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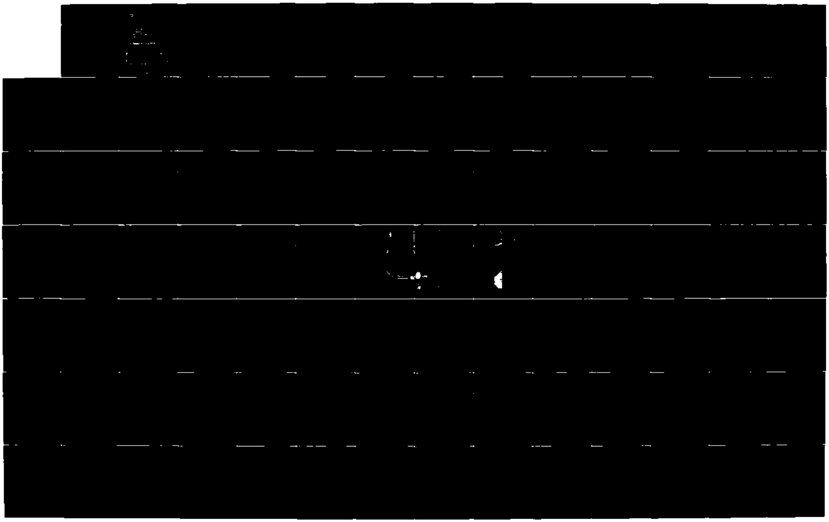

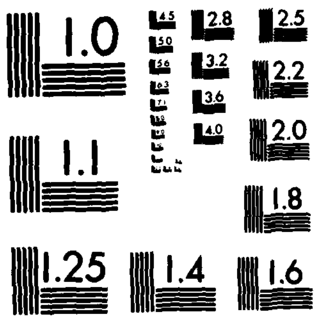

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US Army Corps
of Engineers
Los Angeles District

Santa Ana River Basin, California

Two Dimensional Groundwater and Sediment Modeling Studies

SUMMARY PAPER

Santa Ana River at the Mentone Dam Site

January 1983

Prepared for
The Mentone Task Force

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

Members of the Mentone Task Force are informed of the two dimensional groundwater and sediment modeling studies of the proposed Mentone Dam. Mentone Dam would not have a significant impact on the regional groundwater supply based on experience with similar structures in Southern California area. The objective of this study was to determine the net change in storage and potentiometric levels within the Bunker Hill groundwater basin resulting from construction and operation of Mentone Dam.

Santa Ana River Basin, California

Two-Dimensional Groundwater and Sediment Modeling Studies

SUMMARY PAPER

Santa Ana River at the Mentone Dam Site

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A. SUMMARY

(were evaluated.)

The Los Angeles District Corps of Engineers has evaluated the effects of the proposed Mentone Dam and reservoir sedimentation on net groundwater basin storage and net effect on potentiometric levels (groundwater levels) within the Bunker Hill groundwater basin. It was found that approximately 0.8 square miles of the proposed reservoir area, immediately upstream of the dam, would be affected by sediment deposition under the most severe hydrologic and watershed burn conditions considered reasonable to the area. Gross sediment production rates used in design of reservoir storage allocation were confirmed by use of a mathematical sediment transport model.

The analysis included effects of the dam on historical potentiometric levels and basin storage from water year 1945 through 1980 assuming the dam and sedimentation effects to be in place in 1945.

It was found that no net effect on groundwater basin storage results from the dam and reservoir area with application of relocated groundwater recharge facilities within project limits. Localized depressions in potentiometric levels in the immediate vicinity of the dam would be accompanied by localized increases in potentiometric levels in other parts of the groundwater basin as a result of the project.

B. INTRODUCTION

1. Purpose and Scope of the Summary Paper

This summary paper has been prepared to inform members of the Mentone Task Force of results to date of the Two Dimensional Groundwater and Sediment Modeling studies for the proposed Mentone Dam. A comprehensive report on these studies will be prepared this fiscal year. Representative studies are presented in sufficient technical detail in this summary paper to permit general understanding of study aspects and interrelationships. The report provides summary analysis for (1) infiltration analysis and current distribution patterns of sediments at Southern California reservoirs with similar hydrologic and geomorphologic watersheds, (2) mathematical modeling for sediment production, transport and deposition within the Mentone Reservoir area, (3) groundwater recharge characteristics of the Bunker Hill Groundwater Basin, (4) temporal relationships for potentiometric levels at selected nodal points throughout the basin for pre-project and post project project conditions.

2. Background Leading to the Groundwater and Sediment Modeling Studies

Mentone Dam has been included in a comprehensive flood control plan (the All River Plan) to control flooding along approximately 70 miles of the Main Stem of the Santa Ana River. During the plan formulation process, it was judged that Mentone Dam would not have a significant impact on the regional groundwater supply, based on experience with similar structures in the Southern California area. Spreading grounds, located within the project area, would be relocated as a part of the project.

In early 1981 water districts in the vicinity of the proposed dam began to express concern over the impact of the dam on groundwater supply. In September 1981, the Los Angeles District Corps of Engineers established a task force of citizens (the Mentone Task Force) to deal with major concerns including the impact of the dam on groundwater supply. At a task force meeting in February 1982, the Los Angeles District presented its detailed program to evaluate effects of the dam on groundwater supply and task force comments were received. Assistance has been provided during the study, from local water districts, the U.S. Forest Service, the U.S. Geological Survey, the California Department of Water Resources and Regional Water Quality Control Board, and the Corps of Engineers Hydrologic Engineering Center (HEC) in Davis, California.

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C. OBJECTIVE AND OVERVIEW OF THE STUDY

1. **Objective.** The objective of the Two Dimensional Groundwater and Sediment Modeling studies was to determine the net change in storage and potentiometric levels within the Bunker Hill groundwater basin resulting from construction and operation of Mentone Dam.

2. **Overview of the Study.** The study objective was accomplished by evaluating (1) decreased recharge capability due to sediment deposition at the dam site, (2) increased recharge due to downstream streambed scour, and (3) infiltration associated with relocated recharge facilities by use of a two dimensional finite element mathematical model. Because of the complexity and interrelationship of these and other factors pertaining to aquifer characteristics, mathematical modeling of the conjunctive surface water-groundwater resources of the region was considered appropriate. The limits of the Bunker Hill groundwater basin including streams, faults and existing recharge basins are shown on figure 1.

a. Infiltration Characteristics and Conditions Evaluated for Deposited Sediment at Mentone Dam. The spatial distribution and infiltration characteristics of deposited sediment within the Mentone Reservoir area were determined in order to simulate post-project effects on recharge capability. Deposited sediment characteristics were determined for a broad range of watershed burn and hydrologic conditions. Specifically, sedimentation characteristics were determined under mean annual and Standard Project Flood conditions for both current watershed burn and reasonable maximum watershed burn conditions. Selected representative sedimentation conditions are presented in this summary paper. The mean annual flood associated with the current burn watershed condition was considered to be the most representative condition to be experienced over the life of the project. The sediment deposition pattern resulting from fifty and one-hundred consecutive mean annual flood events are shown for comparative purposes. Sediment deposition for a Standard Project Flood under current watershed burn conditions is also shown in order to demonstrate the effects of a single major flood event.

Infiltration characteristics of deposited and streambed sediments at the Mentone site were determined by evaluating deposited sediments at reservoirs in the Southern California area with similar hydrologic and geomorphologic watersheds (Hansen and San Antonio Dams). Post-project infiltration rates were input to the Two-Dimensional Groundwater Model at nodal points encompassing the reservoir area. The spatial distribution of sediments at these reservoirs were also evaluated. Spatial distribution of deposited sediments at the Mentone site was evaluated by mathematical modeling of sediment production, transport, and deposition phenomena. Mathematical modeling procedures applied at Hansen Dam demonstrated good correlation between mathematically predicted and historical sediment deposition patterns.

b. Downstream Streambed Effects. Streambed scour resulting from relatively sediment free flows from Mentone dam has been considered by increasing infiltration rates within the downstream streambed. Recharge within the downstream streambed would be correspondingly increased.

c. <u>Relocated Groundwater Recharge Facilities</u>. As a feature of the project, impacted recharge facilities would be relocated. Recharge estimated for relocated recharge facilities was based on practical limits demonstrated by local field experience.

d. <u>Calibration and Application of the Two Dimensional Groundwater Model</u>

The study objective was accomplished principally through the calibration and application of a regional mathematical digital model of groundwater flow. This model was used to compute hydraulic head changes in time and space in the basin in response to applied hydraulic stresses. The mathematical model used was the U.S.G.S. "Finite Element--Two-Layer Model for Simulation of Groundwater Flow" prepared in cooperation with the San Bernardino Valley Municipal Water District (August 1979). The nodal and element layout of the groundwater model is shown on Figure 2. Application of the groundwater model began in water year 1945 and extended through 1980. Pre-project conditions assumed that Mentone Dam was not in place. Historical recharge for natural and imported waters and extractions, applied to the nodal pattern, were used to calibrate the mathematical model to the historical potentiometric levels by water year. Pre-project calibrated potentionmetric levels were compared to the post-project levels resulting from the effects of Mentone Dam. Each sediment distribution pattern was applied in 1945 to demonstrate simulated effects as if the condition had been in place from 1945 through 1980. A general plan of the Mentone Dam and reservoir is shown in Figure 3.

D. TECHNICAL DISCUSSION

1. Groundwater Recharge Characteristics of the Upper Santa Ana River Basin (Bunker Hill Groundwater Basin). A review of available literature was conducted to assess groundwater recharge characteristics of the Bunker Hill groundwater basin. Figure 1 shows the limits of the Bunker Hill Groundwater Basin along with contributing streams, recharge basins and known faults.

a. Historical Recharge Values. Part of the surface flow from Mill Creek and the Santa Ana River near Mentone is returned to the groundwater through spreading basins. During the period 1922 to 1955, which includes 11 years of wet conditions and 22 years of dry conditions, it is estimated (Dutcher and Burnham, 1959) that a total of about 170,000 acre-feet of water was recharged to groundwater. This represents an average of about 5000 acre-feet per year. Seasonal fluctuations of the groundwater level in the area have been as much as 120 to 140 feet.

b. Aquifer Properties. Estimated aquifer properties have been obtained from pumping tests in the Mill Creek Basin. Based on these pumping tests, the estimated coefficient of permeability in the Mill Creek basin is about 1,400 gpd/sq.ft.; the coefficient of storage is about 0.05 which is essentially equivalent to the specific yield; and the transmissivity is approximately 100,000 gpd/ft. Older alluvium materials in the Mill Creek basin have estimated coefficients of permeability on the order of 50 gpd/ft^2. In the Mentone basin, however, it is estimated to be as much as 300 gpd/ft^2, which exhibits considerable variability of aquifer properties within a relatively small area. This is due to the diverse geology and varying ages of geologic materials that make up the groundwater storage materials. Extensive systems of faults also exist throughout the area to add to the geologic complexity. Test drilling throughout the area (USGS, 1975) indicates that coarser materials exist in the eastern portions of the Bunker Hill basin with finer grained materials farther west.

c. Infiltration and Recharge Rates. Moreland (1972. p.39) estimated that an average long-term infiltration rate of about 3 ft/day could be obtained for the upper Santa Ana River spreading grounds. This rate was obtained by determining the wetted area of the spreading grounds from aerial photographs and calculating the inflow rate. Infiltration rate was computed by dividing the inflow rate by the wetted area. Using this technique, Moreland (1972, p. 18) calculated infiltration rates of 0.7 ft/day in 1967, 3.7 ft/day in 1969, and 3.3 ft/day in 1970. Moreland (1972) thought that the low infiltration rate of 0.7 ft/day in 1967 might have resulted from accumulated fine sediment on the surface of the spreading basins. The San Bernardino Water Conservation District suggests that if the upper Santa Ana River spreading grounds are well maintained, an infiltration rate of between 7 and 10 ft/day can be obtained. Periodic scarifying of the spreading grounds along with periods of wetting and drying are necessary to maintain a high infiltration rate.

Research conducted by the USGS (1972) and Baumann (1965) determined the magnitude and characteristics of the recharge mound development in the eastern and western basins along the Santa Ana River. Using methods developed by

Baumann (1965) it is estimated that the maximum rate of recharge which the eastern basins could accept without waterlogging is approximately 45,000 acre-feet per year. For the western spreading basins, it was estimated that 35,000 acre-feet per year would be the maximum recharge rate to avoid waterlogging. Therefore, it has been estimated (USGS, 1972) that an artificial recharge rate of as much as 80,000 acre-feet of water per year in the upper Santa Ana River spreading grounds is feasible.

2. Geotechnical Investigations

a. Purpose of Field Exploration. Extensive field explorations have been carried out at Hansen and San Antonio Dams because of their essentially similar hydrologic and geomorphologic watershed characteristics to that of the Mentone dam site. The purpose of these explorations was to evaluate the geotechnical and infiltration characteristics of both the natural and deposited sediment at these existing dams so as to provide a physically realistic framework for estimating infiltration characteristics that could be predicted at the Mentone damsite and to assess anticipated spatial distribution of deposited sediments.

b. Exploration Plan for Hansen and San Antonio Reservoirs. The plans of exploration for the two dams are shown on figures 4 and 5.

An extensive program of bucket-anger drilling and backhoe trenching has been completed. The depths of deposited materials were determined by comparing as-built drawings of basin elevations with the most current basin topographic surveys. In-place permeability tests were run using two methods, depending on the coarseness of materials encountered. Gradations of materials encountered during the explorations were performed, in accordance with Corps of Engineers Engineering Manual 1110-2-1906. The soils were classified according to the Unified Soils Classification System.

(1) Hansen Dam

Sediments were tested over a broad area of the basin where deposition has taken place at depths up to 55 feet below the existing ground surface. In-place permeability tests were performed at six locations.

(2) San Antonio Dam

Because of the large size of deposited sediments, the total area sampled and tested was limited to the finer grained materials near the embankment. Deposted sediments were tested at depths up to 30 feet below the existing ground surface. In-place permeability tests were attempted at five test holes and trenches. Four of the tests were successfully completed. Results were not obtained in test trench 82-7 because the high permeability of materials resulted in water demands too great to keep a constant head during the test.

c. Testing Procedures

(1) Field Permeability Tests. Due to the nature of the materials deposited behind the dams, two techniques were used to measure the field permeabilities (also referred to as percolation or infiltration rates) of the deposited materials. The methods used are in accordance with those for field permeability tests in boreholes as described in designation E-18 of the U.S. Department of the Interior Earth Manual. A summary of the testing procedures follow.

Method 1. Method 1 consisted of drilling a bucket auger exploratory hole to the required depth. A 4-inch (ID) perforated PVC pipe was then placed in the hole and the hole was backfilled with gravel around the pipe. Water was poured into the gravel fill until such time when a measurable head in the pipe was recorded. The water level was then held constant by pumping more water into the hole. Measurements of water flow to maintain constant head in the pipe were recorded.

Method 2. Method 2 consisted of excavating a shallow backhoe pit in the deposted materials. This method was used in more coarse grained material. A 17-inch (ID) steel casing was placed in the pit and the material around the pipe was wetted and then backfilled with a combination of bentonite gel and the least pervious excavated materials available. Water was then poured into the casing. When the water reached a constant elevation, water inflow was measured to maintain this head.

d. Laboratory Tests. Mechanical analysis were performed on representative materials obtained from test holes and trenches in accordance with Corps of Engineers Engineering Manual 1110-2-1906. The soils were classified according to the Unified Soils Classification System.

e. Summary and Discussion of Results.

Plans and logs of exploration for Hansen and San Antonio Reservoirs are shown on figures 4 through 9. Results of in-place permeability tests are shown on tables 1 through 3. Depths of deposited sediments are shown in tables 4 and 5. Gradation curves for composite sediment zone classifications are shown in figures 10 and 11.

(1) Hansen Dam. The majority of materials depsited within the reservoir area are sands, silts and gravels with occasional cobbles and boulders, increasing in relative size in an upstream direction from the embankment. Finer grained materials were encountered relatively close to the embankment or within the 'dead storage' pool area. Sediment types have been combined into composite sediment zone classifications by grouping of sediments encountered. These zones are shown on figure 4 and further discussed herein. Representative gradation curves for these zones are shown in figure 10. Permeability of deposited sediments fall within the expected range for the type of materials encountered. Permeability results are presented along with sediment zone classifications in table 1.

(2) San Antonio Dam. The majority of materials impounded behind San Antonio Dam are coarse sands, gravels, with significant amounts of cobbles and boulders, increasing in relative size in an upstream direction from the embankment. Finer grained materials were confined to the area immediately adjacent to the outlet works and along the toe of the dam embankment similar to the deposition pattern at Hansen Dam. Sediment zone classifications are shown on figure 5. Permeabilities of deposited sediments fall within the expected range for the type of materials encountered and are shown along with test method and sediment zone classifications in table 2. Representative gradation curves for these zones are shown on figure 11.

Before construction of the dam, permeability tests were performed in the foundation. The results of the foundation exploration tests show permeabilities all falling within ranges to be expected for coarse grained materials. The results of those tests are shown in table 3. The location of those tests have been superimposed on figure 5.

(3) Composite Sediment Zone Classification. The materials deposited behind the dams were grouped into four major zones as described in the tabluation below. These zones are based on composite blending of the materials encountered in the exploration trenches and holes. Areal extent of composite sediment zones for Hansen and San Antonio Dams are shown on figures 4 and 5.

Zone	Composite Sediment Zone Classification (Weighted)
I	Clean, well, and poorly graded sands and gravels (SP, SW, GP and GW)*
II	Borderline sands and gravels (SP-SM, SW-SM, GP-GM, and GW-GM)*
III	Sands and gravels with a significant proportion of fines (SM or GM)*
IV	Fine silts (ML or MH)*

* In accordance with Unified Soils Classification System

The sediment zone classifications at Hansen and San Antonio Dams permitted a generalized comparison to the predicted spatial distribution of deposited sediments produced by the HEC sediment transport model at the Mentone Dam site. Zone IV sediments (fine silts) were observed near the embankment and outlet works for both the Hansen and San Antonio Dams. HEC results yielded comparable distribution patterns for fine grained sediments at Mentone. Zone I sediments (sands and gravels) were observed near the upstream reservoir limits at Hansen and San Antonio Dams. HEC results also yielded comparable distribution patterns for coarse grained sediments at Mentone. The sediments tested at existing dams and HEC generated sediment distribution patterns indicated a transition from fine grained sediment near the embankment to coarse grained sediment near the upstream reservoir limits.

The permeabilities for the zones vary from high values in zone I to low values in Zone IV.

(4) Determination of Infiltration Characteristics of Deposited Sediment at the Mentone Dam site. Methodology devised by Moreland (1972) was used to evaluate the infiltration rate of both the natural and deposited sediment materials. Based on analyses of the field percolation test data and the corresponding grain size distribution of the soil at the existing Hansen and San Antonio Dams, a nearly straight line relationship on log-long scale was established between the infiltration rate in ft/day and the dimensionless grain size factor D_{20}/S_0 where S_0 represents the 20th percentile particle diameter corresponding to 20 percent finer on the grain size graph and S_0 represents a sorting coefficient whose value equals the square root of the ratio of D_{75} and D_{25} particle sizes ($\sqrt{D_{75}/D_{25}}$). This relationship is graphically presented on figure 12.

Based on the results of geotechnical field explorations of the Mentone dam site, infiltration rates of the native materials in the reservoir area were evaluated. This represents pre-project conditions. Inasmuch as the sediment-delta formation over part of the reservoir area tends to affect infiltration rates, new recharge rates were computed based on the composition and depth of the deposited material within the sediment delta. The recharge rates for the post-project conditions along with that of the pre-project condition are summarized in a dimensionless form in table 6. Infiltration rates for nodal points corresponding to the approximate effected area of the dam and sediment delta were reduced by use of dimensionless factors presented in table 6.

3. Watershed Sediment Investigation for the Upper Santa Ana River, Big Bear Lake to Mentone

a. Purpose and General Approach.

The purpose of the watershed sediment investigation was to evaluate long-term effects that sedimentation may have on recharge capability in the Mentone reservoir area by (1) predicting where sediment would deposit in the reservoir over the life of the project, and (2) determining whether sufficient quantities of material will settle out to reduce groundwater recharge infiltration rates within the reservoir. To do this, methods for determining the quantities of sediment that would reach the reservoir for various hydrologic events and forest conditions were developed. Once the hydrologic and sediment production rates were determined, methods for simulating the development of the reservoir sediment delta (the sediment deposition pattern) were applied using data that characterize key geologic and hydraulic features of the watershed and proposed reservoir.

Simple empirical mass volume procedures yielded rough estimates of the extent and thickness of delta materials but offered little detail about the distribution or character of different sediment materials or reasonable delta shapes. This led to the need for a more sophisticated modeling approach. Computer program HEC-6 "Scour and Deposition in Rivers and Reservoirs" (HEC, 1977), was used to route sediment into the reservoir pool and to simulate the temporal and spatial development of the delta deposits. This simulation

program is particularly useful for analyzing the impact of changes in energy gradient, in-flowing sediment load or bed material grain size on future trends in reservoir sedimentation. The model is known to exhibit good overall correlation between computed results and available data based on sediment surveys at the Hansen Dam in southern California and is thus considered a reliable predictive tool for simulation of future trends of reservoir sedimentation and scour.

b. Erosion and Sediment Production.

The occurrence of erosion due to surface runoff and channel flows is common in southern California. The amount of sediment production varies among watersheds and from year to year and storm to storm. The amount also varies with the age and condition of the watershed vegetation, tending to decrease as the age and density of the vegetation and litter cover increase. Because of the physiographic features of the study area, some erosion and sediment production may be expected during severe storms even with the best "normal" vegetation conditions in the watershed. However, normal sediment production, when averaged over a long period of time, remains relatively constant.

(1) Special Factors Affecting Sediment Production and Delivery.

There are four major factors affecting the rates of sediment production from watersheds in the Upper Santa region, they are (1) accelerated geologic activity--accelerated geologic activity includes dry (ravel) erosion and local landslide activity, (2) periodic occurrence of forest and brush fires, (3) off-road recreational activities, and (4) the combined effects of agriculture, urbanization and construction development. Over the period of several years, sediment contributions from natural geological activities tend to be relatively constant. Factors (3) and (4) contribute far less sediment to the total basin-wide sediment budget than do (1) and (2). Factors (3) and (4) also tend to be localized and are, therefore, more quantifiable.

Perhaps the single most important factor affecting erosion in the Upper Santa Ana River drainage area is the occurrence of fires. Removal of protective vegetation by fire greatly increases runoff and subsequently, erosion rates. Erosion and sediment production will continue at greater than normal rates from the time the watershed is burned until it has recovered sufficiently to exert its normal control over runoff and erosion. Therefore, vegetation within a watershed may vary in value for protection purposes after a fire. It will have a minimum value immediately after the fire and a maximum and relatively constant value when fully recovered and normal soil-water relations have been reestablished. Methods perfected by Rowe, Countryman and Storey (1949 and 1954) were used to determine the effects of fires and fire frequency on peak discharge and erosion rates throughout the drainage area.

(2) Contributing Watersheds.

In order to evaluate sediment sources and transport mechanisms in the proposed Mentone dam area, the total contributing drainage basin was subidivided into seven subbasins. Each subbasin was then examined individually based on its physiographic character, geology, soil type,

hydrology and fire history. Contributions of runoff and sediment into the project site from each subbasin were determined. The total drainage area above the Mentone damsite covers 260 square miles. Big Bear Dam controls about 38 square miles, and there are a few additional locally controlled drainage areas. The effective contributing drainage area for sediment production and yield for the entire drainage basin is approximately 211 square miles.

Figure 13 presents a schematic diagram of the Upper Santa Ana Basin and delineates the contributing watersheds used for this investigation. The following discussion will present results from the sediment investigation for these watersheds.

(3) Representative Hydrologic Conditions and Sediment Production Rates.

The mean annual storm and standard project flood with ungated reservoir operation were used throughout this investigation in order to bracket the range of all possible hydrologic events. Detailed descriptions of the hydrologic characteristics of these events are presented in the "Hydrology Section" of the Santa Ana River Phase I GDM (U.S. Army Corps of Engineers, 1980). These events were then applied to two different forest conditions based on forest fire history. The resulting sedimentation conditions were assumed in place at the Mentone site in 1945 and the resulting effects on historical groundwater levels were then evaluated through 1980. The extent and frequency of fires directly affect the amount of runoff and sediment production from a watershed and are, therefore, important factors to consider for simulating the hydrologic response of a watershed. "Current burn" forest conditions were based on what currently exists throughout the drainage area with respect to the extent and dates of past forest fires. Details for the determination of current forest conditions and past fire histories were obtained from the U.S. Forest Service (1982) and the San Bernardino County Flood Control District Fire Statistics (1980).

A hypothetical "reasonable maximum burn" condition was developed to depict the worst likely watershed conditions that could ever occur due to forest fires. The 'one time' effects of this condition were used to analyze sediment production and distribution from a single hydrologic event occurring when the watershed was in its most erodible condition. It was not considered representative of general watershed conditions throughout the life of the project. Development of this condition was closely coordinated with recommendations from personnel from the U.S. Forest Service in San Bernardino, California. It was based on the amount and types of burnable materials within the watershed and on other important factors such as worst possible wind conditions. The resulting "reasonable maximum burn" condition would totally burn 100 percent of Big Bear Lake, Plunge Creek, Oak Creek, Mill Creek Wash and Morton Canyon drainages, while burning fifty percent of the total area within the Santa Ana River and Mill Creek subbasins. Reasonable maximum burn conditions also assume that the burn is recent and that there has been no time for forest recovery.

The representative hydrologic and watershed burn conditons used in the analysis are shown in the following tabulation.

Pre-Project Simulation

Condition "0" --- Mean Annual Flow, Current Burn Condition

Post-Project Simulations Reflecting Sediment Delta Formation

Condition "1" --- Mean Annual Flow, Current Burn Condition
Condition "2" --- Mean Annual Flow, Reasonable Maximum Burn Condition
Condition "3" --- Standard Project Flood, Current Burn Condition
Condition "4" --- Standard Project Flood, Reasonable Maximum Burn Condition
Condition "5.0"-- Mean Annual Flows, 50-yr. Simulation, Current Burn Condition
Condition "5.1"-- Mean Annual Flows, 100-yr. (extrapolated) Simulation, Current Burn Condition

(a) Average Annual Sediment Production - Estimated average annual sediment production rates under current burn conditions for each of the seven contributing watersheds from Big Bear Lake to Mentone are summarized in table 7. As indicated in Table 7, sediment production was adjusted within each subbasin according to past burn history. Column 5 lists the fire years and the approximate percentage of the total subbasin area that was burned. These data were applied to the tables and procedures developed by Rowe, Countryman, and Storey (1949 and 1954) to estimate a current burn factor and finally a value of sediment yield. If a fire had occurred twelve years previously, it was assumed that the forest had returned to its natural state and the burn adjustment factor was one. Table 8 presents a summary of the estimated amounts of sediment production for reasonable maximum burn conditions due to mean annual rainfall. A total estimated average annual sediment production from Big Bear Lake to Mentone with current burn forest conditions is approximately 270 ac-ft/yr. With reaonsable maximum burn conditions, the annual sediment production is approximately 3340 ac-ft/yr. This is based on the assumption that all of the sediment delivered to the Santa Ana River from contributing watersheds continues through the system until it reaches the proposed Mentone dam site. This represents a basinwide weighted average seidment yield of approximately 1.28 acre feet per square mile for current burn conditions and 15.9 acre feet per square mile with reasonable maximum burn conditions.

(b) Estimated Standard Project Flood Sediment Production. Estimation of sediment production and delivery due to intense rain storms is a difficult task due to many complicating factors. Such factors include climatic variability, differences in local and area-wide geology, antecedent moisture content of the soil, river flow conditions and the character and availability of surface and channel sediment prior to the event.

As with the mean annual sediment estimates, methods developed by Rowe, Countryman and Storey (1949 and 1954) were used to estimate the sediment production and delivery as a result of the standard project flood. Their procedures were not directly applicable, however, due to the extreme magnitude of the SPF event. Individual peak discharge frequency curves were developed for both watershed burn conditions for each subbasin. These curves were then used to determine the peak SPF discharge from each subbasin for both burn conditions. This provided values of peak runoff from each subbasin. Next,

erosion rates for both burn conditions for each subbasin were determined using the estimates of peak runoff from each subbasin. This procedure provided values for the volume of sediment produced from each subbasin as a result of an SPF storm event (cu.yds./storm). Table 9 presents a summary of these results along with the estimated values for basin wide sediment yield under current burn and reasonable maximum burn conditions.

c. Extent, Shape and Character of Sediment Deltas.

(1) Application of Computer Program HEC-6

In order to provide an accurate description of the delta shapes, thicknesses and spatial distributions of deposited sediment materials, computer program HEC-6 "Scour and Deposition in Rivers and Reservoirs" (HEC, 1977) was applied. Computer program HEC-6 is a generalized sediment transport mathematical model. It has been widely used throughout the Corps and by private industry to simulate long term streambed profile behavior. By mathematically coupling sediment transport processes and stream hydraulics, HEC-6 effectively simulates (1) scour and deposition, (2) accounts for streambed armoring and hydraulic sorting of up to sixteen different sediment grain sizes, (3) allows tributary inflow and/or diversions of both sediment and water, and (4) graphically displays the input and output.

For the purpose of this investigation, HEC-6 was used to route the estimated amounts of sediment and runoff (as summarized in the preceding section) into the proposed Mentone Reservoir. Once these sediments reached the reservoir, sophisticated settling algorithms within the code simulated selective transport and deposition of the various grain sizes of sediment in the reservoir pool. Thus, a reservoir delta forms as layers of sediment continue to deposit during an event. The model simulates the longitudinal changes in shape, thickness and grain size for the sediment delta deposits. It also computes the reservoir trap efficiency and total volume of sediment deposited in the reservoir. The whole process takes into account the repeated filling and emptying of the reservoir with successive flood events. Exposed delta deposits from previous events will move toward the dam as they are scoured by high flow during the filling and emptying of the reservoir with each large event. Simulations were carried out for all the hydrologic and watershed conditions discussed under paragraph 3.b.(3).

d. Summary and Discussion of Results.

Table 10 summarizes the computed depths of deposited sediment (delta thickness along the low point of the streambed) for the six different conditions that were simulated. Delta profile (spatial distribution of sediment deposits) for conditions "3", "5.0" and 5.1 are graphically shown on figures 14 through 16. Sedimentation profiles corresponding to these conditions are shown on figures 17 through 19. These conditions were selected for this summary paper because they generated the maximum depths of sediment materials in the reservoir area and are representative of reasonably severe theoretical scenarios that may be expected in the basin. Grain size curves for existing foundation materials at the damsite are shown on figure 20. Composite gradation curves for conditions "3", "5.0" and "5.1" are also shown on figures 21 and 22.

(1) General Discussion.

Results of this investigation indicate that sediments subject to deposition within the Mentone Reservoir over the project life of the dam will be confined to approximately a 0.8 square mile area in the vicinity of the outlet. The simulated delta characteristics for all deposited sediments showed reasonable and conservative correlation to those observed in reservoirs with similar hydrologic and geomorophologic watersheds in southern California. (See paragraph 2.e.(3))

This determination was made with consideration to forest fire burn histories within the watershed and short term increased sediment production rates resulting thereof.

(2) Mean Annual Flood Condition. Consecutive mean annual flood events and the sediment deposition resulting thereof was considered the most representative simulation of sedimentation conditions to be expected at the Mentone damsite over the life of the project. Under current watershed burn conditions sediment production associated with mean annual flows was 270 acre feet per year. Over a 50 year period this resulted in deposition of about 6 feet near the outlet, increasing to about 34 feet at 4000 feet upstream of the embankment. An extrapolated 100 year condition resulting from consecutive mean annual flows resulted in deposition of about 10 feet near the outlet, increasing to 53 feet at 4000 feet upstream of the embankment. Under a single mean annual flood event associated with a reasonable maximum watershed burn condition deposited sediments were confined to an area from the outlet works to about 4000 feet upstream of the embankment.

For all watershed burn conditions, individual or consecutive mean annual events resulted in essentially no sediment deposition from about 4000 feet upstream of the embankment to the upstream project limits.

(3) Standard Project Flood Condition.

The standard project flood was considered to be the most severe individual hydrologic event which would result in sediment deposition in the reservoir area. Under current watershed burn conditions this would result in deposition of less than 1 foot near the outlet increasing to a maximum of about 3 feet at 6000 feet upstream of the embankment. Deposition would be coarse grained and essentially of similar composition to existing streambed materials from about 4500 feet upstream of the embankment to the upstream project limits. Under reasonable maximum watershed burn conditions deposition would be an average of about 6 feet from the outlet works to the upstream project limits. Composition of these sediments would be similar to existing streambed materials.

The standard project flood, under existing conditions would result in deposition and/or scour over the entire Santa Ana River flood plain (i.e., from north of Greenspot Road to the Redlands Airport). Under post-project conditions, with Mentone Dam, the Standard Project flood would result in moderate deposition (6 feet average) under the most severe watershed burn conditions and in minimal deposition (1 foot average) under current burn

conditions. Post-project deposition would be of similar composition to existing streambed materials from about 4500 feet upstream of the embankment to the upstream project limits.

For an SPF event, restoration requirements for recharge facilities and post flood recharge capability would be comparable, with or without Mentone Dam in place, from about 4500 feet upstream of the embankment to the upstream project limits.

4. Two-Dimensional Groundwater Modeling Study

a. Salient Features of the Mathematical Model.

A conceptual approach to groundwater modeling was used in applying this model. Essentially, a conceptual model of the groundwater system, which represents the reduction of the prototype to its principal elements, was developed. This is followed by the development of a mathematical model that represents, to a good degree of approximation, the conceptual model. A generalized conceptual model of groundwater system for the upper Santa Ana River Basin is shown in Figure 1. The development of the mathematical model is based on the generalized concept, namely inflow minus outflow equals delta storage. This conceptualization yields a system of differential equations describing the groundwater basin's ability to receive, store and transmit water. The resulting system of equations is then computationally solved for the output or dependent variable in conjunction with physically realistic initial and boundary conditions using a digital computer.

More specifically, the mathematical model used for the simulation of groundwater flow of the basin represents the prototype of a two-aquifer system. The two aquifer units are linked in the model through a leakage term that represents vertical flow through the confining layer of clay and silt deposits of varying thickness and hydraulic conductivity. The model is based on a Galerkin finite-element approach, originally developed by Pinder and Friend (1972) and subsequently modified by Durbin (1979) of the U.S.G.S. This formulation using (triangular) finite-elements was chosen because it provides a more flexible and precise simulation of irregular boundaries and faults that characterize the basin.

The mathematical equation that depicts the flow of water in each aquifer unit of a two-layered model is:

$$\frac{\partial}{\partial x}\left(T\frac{\partial h}{\partial x}\right)+\frac{\partial}{\partial y}\left(T\frac{\partial h}{\partial y}\right)-S\frac{\partial h}{\partial t}-W-\frac{K}{b}(h-h_a)=0$$

where:

- T = transmissivity of aquifer,
- h = hydraulic head in aquifer,
- S = storage coefficient of the aquifer,
- W = flux of a source or sink (pumpage or recharge),
- K = vertical hydraulic conductitivity of the clay layer that separates the two aquifers,

b = thickness of the clay layer,
h_a = hydraulic head in the adjacent aquifer,
x and y = cartesian coordinates, and
t = time.

It should be noted that for simplicity, the upper (layer 1) and the lower (layer 2) layers of the mathematical model have identical grid patterns, with the elements and nodes numbered the same for each layer. The nodal network consists of 296 elements and 178 nodes, as shown on Figure 2. The physical properties of the aquifers such as transmissivity, storage coefficient, and where appropriate, the thickness and vertical permeability of the confining clay layer, are assigned to elements, and the recharge, discharge, and potentiometric head are assigned to the nodes. The elements are more closely spaced where data are more abundant in the confined aquifer zone. The key wells used in facilitating comparative analysis and correlation between the historical and simulated water levels for both the pre-project and post-project conditions as well as areas of artificial recharge of imported water were also made nodal points for this study for a more precise simulation of groundwater flow conditions in the basin.

b. Input Data.

(1) Aquifer Parameters - Values of transmissivity and storage coefficient for the water-bearing deposits and leakance coefficient for confining clay bed between the upper and lower aquifer units.

Aquifer transmissivity values throughout the basin and the storage coefficients for the part of the basin where the aquifer is unconfined were originally derived by the California Department of Water Resources. Estimates of transmissivity were based on well-capacity tests. Storage coefficients for the unconfined aquifer were derived by assigning yield values to different materials encountered in about 1,100 well-drillers' logs. The storage coefficients for the confined aquifer were determined from aquifer performance tests in the study area and other areas with similar aquifers. Transmissivities ranged from 5,000 gpd/ft along the San Bernardino Mountain front to about 500,000 gpd/ft in the center of the basin in the confined zone. Values of aquifer storage coefficients used in the model ranged from 0.15 in the unconfined aquifer zone to 0.0001 in the confined aquifer zone.

The confining bed is a semipermeable clay layer through which groundwater is transmitted more or less vertically between the underlying and overlying aquifer units. Leakage, expressed as the "leakance coefficient" is the ratio of hydraulic conductivity to the thickness of the confining bed. The leakance coefficient in the confined part ranged from 0.0012 to 0.0009 ft/day/ft. In the unconfined part of the basin, the confining layer was assumed to be 1 ft thick and the leakance coefficient was assigned a constant value of 0.03 ft/day/ft based on available data.

(2) Initial Conditions. Measured water levels during Spring 1945 form the initial conditions for the simulation of 1945-1980 period for both the pre-project and post-project conditions.

(3) Boundary Conditions. Boundaries define the geographic area referred to as the simulation domain of the model. The general boundary of the model coincides primarily with faults and other barriers consisting of either zero-flow segments along consolidated-rock boundaries or constant-flow segments in the unconsolidated deposits where groundwater flows across or over the faults. In areas where fault boundaries are not well-defined and the unconsolidated deposits extend beyond the study area, the model boundaries were chosen so that the cause-effect relationship (pumpage and recharge) outside the model boundaries would have minimal effect on the flow system inside the simulation domain.

An impermeable (zero-flow) boundary was assigned to the front of the San Bernardino Mountains along the San Andreas fault zone, except where the numerous streams enter the alluvial basin. These streams are modeled as recharge (or constant-flow) boundaries through which surface water and underflow enter the model area as groundwater recharge. Barrier E along the northwest side of the model has an extremely low transmissivity and is considered a zero-flow boundary.

Constant-flow segments of the model boundary were assigned for areas of recharge (spreading basins) or discharge (pumping wells). A constant outflow of 15,200 ac-ft/yr was assigned to San Jacinto fault, based on U.S.G.S records. Recharge as groundwater underflow across the Crafton Fault ranged from 5,350 to 8,150 ac-ft/yr. In addition, the various faults and barriers traversing the simulation domain constitute zones of low hydraulic conductivity, and are treated as such in the model.

It should be noted that the confining clay layer in the artesian area separates the upper and lower model layers, the demarcation between the upper and lower layers being dependent on the measured water levels across the impediment. In addition, the demarcation between the confined and unconfined aquifer zones in the basin is based on the relative thickness and the vertical hydraulic conductivity of the confining clay layer as well as on the difference in water levels between the upper and lower aquifer units.

The bottom of the water-bearing alluvium or top of the consolidated bed-rocks constitutes the bottom of the model on the basis of permeability contrasts along this interface.

(4) Recharge and Discharge. Available data show that except during floods of high frequencies, the inflows are much larger than the outflows. Consequently, a substantial part of the surface flow that enters the basin through the various tributaries from San Bernardino Mountains enters the groundwater reservoir through percolation from the permeable river beds as well as through diversion into existing recharge basins. During the period 1945-1980, the net surface flow available for groundwater recharge was of the order of 108,000 ac-ft/yr. Detailed pumpage records were also obtained from local water agencies for this period.

An evaluation of recharge and infiltration characteristics is presented in paragraph 2.e.(4).

c. Calibration and Verification of Mathematical Model.

Although the approach delineated herein is based on physical principles and presents a powerful tool for the solution of mathematicl models of complicated subsurface hydrologic systems, such as the one under consideration here, appropriate model testing, calibration and verification procedures must be undertaken to ensure that the adopted algorithm yields reasonable results prior to its application to post-project conditions.

Calibration refers to the process of adjusting input hydrologic parameters to the model until differences between model simulations and field observations are within acceptable limits. This is accomplished primarily through sensitivity analysis, namely by holding all input parameters constant but one, and perturbing the last one such that variation of the dependent variable can be examined. If small perturbations of the parameter produce large changes in the dependent variable, the system is said to be sensitive to that parameter. This gives a measure of how accurately that parameter must be estimated if the model is to be used in prediction. On the other hand, if the dependent variable is not particularly sensitive to the perturbed parameter then the value of the parameter need not be accurately estimated for prediction purposes. Furthermore, if the system is extremely insensitive to the perturbed parameter, the parameter and its associated system component may be redundant and could be deleted from the model. The model calibration and verification are not complete without a thorough sensitivy analysis. The calibration process is a complex, interwoven task of adjustment and readjustment; it is indeed a means of modifying and improving conceptual views of the aquifer system. A test was made to determine if the difference between simulated and historical heads in selected observation wells could be accounted for by a likely range of errors in input parameters. The test thus provided a measure of reasonableness of the calibration process. Based on the results of a detailed sensitivity analysis principal parameters, namely transmissivity, storage coeffieicnts, vertical hydraulic conductivity of the confining clay layer, initial water levels as well as magnitudes and distribution of groundwater recharge were each independently changed by plus or minus a constant factor while other parameters were unchanged. The range of values differed for each parameter and reflected a subjective estimate of the likely range of variation in each parameter. Care was exercised not to vary input parameters much from known field values, and changes were made on an areal rather than node-by-node basis.

Simulated potentiometric heads obtained early in the process represented an initial conceptual view based on much of the available data from U.S.G.S. and California Department of Water Resources. The match between the simulated and observed potentionmetric surfaces was improved and the conceptual view was modified by adjustment of input parameters, while staying within a reasonable expected range of variation in their values. These aspects pertaining to pre-project conditions along with detailed post-project simulations are presented in the next section.

d. Simulation Strategy.

(1) Pre-Project Simulations.

Using available values of aquifer parameters as well as those of recharge and pumpages, several runs were made to evaluate the sensitivity of significant model input parameters. Sensitivity analysis indicates that transmissivity, initial water levels and recharge are the most sensitive parameters. In accordance with the procedure delineated earlier, transmissivity values of the upper aquifer unit primarily in the confined zone, initial water levels particularly in the northern part of the basin as well as magnitude and distribution of artificial recharge pertaining to imported water for the 1975-1980 period were adjusted (within ± 10 percent of their initially estimated values) so as to obtain the best possible correlation between the simulated and historical water levels over most of the basin. These adjustments yield good correlation between the simulated and historical water levels for the period 1945-1974. However, the correlations for the period 1975-1980 were not as good. Further analysis indicates that considerable improvement between the simulated and historical water levels results for the entire simulation period 1946-1980 when 75-100 percent of the imported water entitlement is used (instead of either 50 percent or 100 percent entitlement) for the period 1975-1980 and 50 percent for the 1973 and 1974 water year period. This is reasonable because not all of the imported water (assuming that it is known with a high degree of precision) is effectively utilized due to losses in the system, primarily attributable to:

- evapotranspiration loss
- detention and depression storage
- water retained in the unsaturated zone

The computed potentiometric levels along with the corresponding historical levels are graphically presented on Figures 23 through 27, for selected nodes. Final simulated heads agree reasonably well with observed heads, although there are a few isolated locations within the confined aquifer zone where the correlation is not as good. The difference can generally be accounted for by the likely range of error or uncertainty in one or more of the input parameters.

The computed potentiometric levels presented on these figures constitute the final pre-project calibrated levels; these will be used for comparisons to with the computed water levels corresponding to various post-project conditions pertaining to the anticipated impact of Mentone Dam on the groundwater resources of the basin.

(a) Pre-Project Recharge at Mentone Dam Site.

Pre-project recharge for natural and imported water was distributed at various nodes representing recharge basins and streambed locations along the Santa Ana River main stem. Recharge quantities were adjusted at nodes within the Mentone reservoir limits and along the river until good correlation was obtained with historical potentionmetric levels in the vicinity.

(2) Post-Project Simulations

Using the final, calibrated pre-project run as the basis, necessary modifications in the input data were made to reflect the effect of various post-project conditions. Recharge or infiltration rate is the only model parameter that is subject to modification due to anticipated sediment delta formation associated with the Mentone Dam in-place. The following procedure was adopted for the simulation of post-project conditions:

(a) Infiltration Rates.

Infiltration rates for the nodes overlying the reservoir area and the existing recharge basins in the vicinity of the Mentone damsite subject to sediment delta deposition were adjusted downward in accordance with the infiltration rate vs. dimensionless grain size factor relationship (shown on figure 12 with results summarized on table 6) for each of the hydrologic and watershed conditions. Consequently, quantities of net recharge were computed for each node affected and were inputted into the simulation model.

(b) Potential Loss of Recharge.

Difference in the recharge values between the pre-project and each of the post-project conditions termed as "potential loss of recharge" due to sedimentation effects in the Mentone reservoir area are summarized in Tables 11 through 13 for conditions "3", "5.0", and "5.1". As indicated earlier, the areal extent of sediment delta is limited to approximately 0.8 square mile in the reservoir area.

(c) Increased Downstream Recharge.

The accumulation of sediments in the reservoir area would render the water leaving the damsite relatively sediment-free. It, therefore, follows that the recharge potential of the Santa Ana River downstream of the damsite would be correspondingly enhanced.

Based on wetted area and temporal relationships for flows leaving the Mentone Dam, approximately 700 ac-ft average annual increase in infiltration would take place under current sediment conditions in Santa Ana River in the reach between Mentone Damsite and Warm Creek. This is attributable to all flood flows greater than 2,000 cfs being stored behind the dam and released at the 2,000 cfs rate for duration ranging from 5 to 21 days depending upon the frequency of the flood. The analysis further indicates that infiltration rates would experience an order-of magnitude increase in the downstream reaches of Santa Ana River as a result of streambed scour. This has been taken into consideration in the mathmatical model.

(d) Increased Recharge - Relocated Recharge Facilities within Project limits. Relocation of spreading facilities within available project areas is presented as one of several alternative recharge methods and locations to recover potential loss of recharge due to sedimentation effects in the reservoir area. Additional methods and locations are discussed in this and the following sections. Sediment deposition patterns with the Mentone

Reservoir area indicate that from about 4500 feet upstream of the dam to the upstream project limits (about 9000 feet upstream of the dam) would be essentially free of deposited sediment. The area immediately upstream and downstream of the spillway and near the downstream outlet portal would be free of streamflow and sediment deposition due to the protective benefit afforded by the Mill Creek levee and dam embankment, respectively. These areas comprise about 1.0 square mile (over 600 acres) of streambed area, suitable for recharge operations. Based on a practical recharge relationship of 1.5 cfs per wetted acre, potential recharge loss due to reservoir sedimentation would be effectively offset through relocation of recharge basins to these areas for both natural flow and future imported water entitlements through year 2000. Alternative recharge methods could also include injection wells and recharge pits. Post-project recharge, placed at nodes located generally upstream of the reservoir limits, was used to simulate the effects of relocated recharge facilities.

Tables 11 through 13 summarize the redistribution of recharge quantities over the various nodes for each of the post-project conditions. These recharge quantities were also inputted into the model. The simulated post-project potentiometric levels along with the calibrated pre-project levels for selected nodes are presented in figures 28 and 48.

(3) Additional Recharge Capability Not Included in this Study.

(a) Additional Recharge Potential-Upstream Recharge Facilities. Addition of new recharge basins, reshaping existing recharge basins for hydraulic efficiency, and injection wells could further enhance recharge upstream of the project limits.

(b) Additional Recharge Potential-Downstream Recharge Facilities. Placement of downstream in-channel or off-channel spreading facilties in conjunction with relatively sediment-free flows leaving the Mentone Dam could also increase recharge capability. An example of the highly beneficial use of downstream recharge facilities in conjuntion with Corps of Engineers flood control dams can be demonstrated at Whittier Narrows Dam, Santa Fe Dam, Hansen Dam and Prado Dam.

E. CONCLUSIONS

1. There would be no impact on basin-wide groundwater storage due to the placement of Mentone Dam including application of relocated recharge facilities. There would be localized depression in groundwater levels in the vicinity of the dam, accompanied by water level rises of the same order of magnitude in other parts of the basin.

2. The mathmatical model used for the simulation of groundwater flow within the upper Santa Ana River Basin in this study provides a reliable method for predicting the effects of the proposed Mentone Dam on the groundwater resources of the region. Good correlations were obtained between the simulated and historical water levels in approximately a dozen existing U.S.G.S. observation wells encompassing both the confined and unconfined aquifer zones within the basin during the 1945-1980 simulation period.

3. Based on the results of detailed sensitivity analysis for the range of aquifer characteristics as well as the watershed and hydrologic conditions during the 1945-1980 simulation period, it was found that, in terms of piezometric variations, the lower aquifer layer is not particularly sensitive, to all available input data.

4. Mathmatical modeling of sediment deposition patterns in the Mentone reservoir area shows reasonable and conservative correlation to that experienced in nature, based on an evaluation of deposition patterns at existing reservoirs with similiar hydrologic and geomorphologic contributing watersheds in Southern California.

5. Infiltration analysis indicates that except for the recharge facilities located in the reservoir area in the immediate vicinity of the dam outlet (confined to approximately 0.8 square mile area), there will be no impact on the existing reacharge basins upstream of the reservoir area corresponding the most severe hydrologic and watershed scenarios considered reasonable to the area. Approximately 1.0 square mile of land area within the project limits, essentially free of sediment deposition, would be available for relocated recharge facilities. Relocated recharge facilities as well as increased downstream infiltration due to streambed scour would effectively offset loss in recharge due to sedimentation effects of the dam. Alternative recharge methods are also available to further enhance recharge capability.

Table 1

Permeability Results

Hansen Dam

Test Hole or Trench Number 1/	Permeability (ft/day)	Method	Composite Sediment Zone Classification
TH 82-3A	22	(1)	II
TH 82-9A	5.8	(1)	III
TH 82-10A	3.1	(1)	III
TH 82-11A	3.5	(1)	III
TH 82-12A	3.3	(1)	III
TH 82-5A	5.2	(1)	III

1/ Refer to figure 4 for locations of test holes and trenches.

Table 2

Permeability Results

San Antonio Dam

Test Hole or Trench Number[1/]	Permeability (ft/day)	Method	Composite Sediment Zone Classification
TH 82-3A	9.3	(1)	II
TH 82-4	6.3	(1)	I
TH 82-5	3.8	(1)	III
TT 82-7	[2/]	(2)	I
TT 82-11	60+	(2)	I

[1/] Refer to figure 5 for locations of test holes and test trenches.

[2/] High permeability of materials resulted in water demands too great to keep a constant head during the test.

Table 3

Foundation Exploration[1]

Permeability Test Results

San Antonio Dam

Test Pit No.	Elev. of Test (ft)	Depth (ft)	Test Run No.	Permeability (ft/day)
12	2133	1	1	4.8
	2124	10	1	27.3
			2	20.1
	2119	15	1	10.5
			2	9.1
	2114	20	1	50.0
			2	22.2
	2104	30	1	41.3
			2	32.5
	2094	40	1	52.0
			2	36.4
	2084	50	1	43.7
			2	19.3
	2074	60	1	391.0
13	2113	1	1	17.3
		2		15.1
	2109	5	1	18.6
			2	17.6
	2104	10	1	36.7
			2	30.6
	2099	15	1	386.0
			2	332.0
	2094	20	1	43.5
			2	21.9
	2084	30	1	34.4
17	2095	50	1	16.3
19	2160	45	1	54.2
			2	43.7

[1] Taken from San Antonio Dam Seismic Evaluation, Phase I, January 1980.

Table 4

Depth of Deposited Sediments

Hansen Dam

Co-Ordinates Northings	Eastings	Depth (ft.)*
207,500	171,500	15
	172,000	19
	172,500	25
	173,000	53
	173,500	42
	174,000	47
	174,500	24
208,000	170,500	17
	171,000	18
	171,500	17
	172,000	16
	172,500	49
	173,000	47
	173,500	48
	174,000	28
	174,500	20
	175,000	3
208,500	171,000	30
	171,500	49
	172,000	18
	172,500	12
	173,000	13
	173,500	42
	174,000	35
	174,500	7
209,000	171,000	27
	171,500	30
	172,000	56
	172,500	43
	173,000	15
	173,500	42
	174,000	8
	174,500	0
	175,000	0

Co-Ordinates Northings	Eastings	Depth (ft.)*
209,500	171,000	19
	171,500	21
	172,000	63
	172,500	42
	173,000	34
	173,500	31
	174,000	10
	174,500	7
	175,000	6
	175,500	-7**
	176,000	4
	176,500	5
	177,000	3
	177,500	0
	178,000	3
	178,500	0
	179,000	0
210,000	171,500	23
	172,000	3
	172,500	39
	173,000	34
	173,500	7
	174,000	1
	174,500	13
	175,000	8
	175,500	6
	176,000	9
	176,500	7
	177,000	4
	177,500	3
	178,000	4
	178,500	1
	179,000	2
	179,500	3
	180,000	-2

Co-Ordinates Northings	Eastings	Depth (ft.)*
210,500	171,000	7
	171,500	3
	172,000	4
	172,500	3
	173,000	4
	173,500	0
	174,000	10
	174,500	4
	175,000	6
	175,500	8
	176,000	1
	176,500	1
	177,000	1
	177,500	3
	178,000	7
	178,500	3
	179,000	7
	179,500	12
	180,000	5
211,000	171,500	-3
	172,000	1
	172,500	2
	173,000	0
	173,500	2
	174,000	1
	174,500	3
	175,000	5
	175,500	2
	176,000	0
	176,500	1
	177,000	1
	177,500	2
	178,000	1
	178,500	4
	179,000	5
	179,500	3

Co-Ordinates Northings	Eastings	Depth (ft.)*
211,500	171,500	2
	172,000	5
	172,500	-2
	173,000	-0
	173,500	3
	174,000	2
	174,500	0
	175,000	4
	175,500	0
	176,000	0
	176,500	0
	177,000	1
	177,500	0
	178,000	1
	178,500	3
212,000	174,500	3
	175,000	5
	175,500	1

* Depths of deposited materials as of survey dated October 1978.
** Negative numbers show erosion below that of the finish grade after construction.

Table 5

Depth of Deposited Materials

San Antonio Dam

Co-Ordinates Northings	Eastings	Depth of Deposited Materials (ft.) 1/
728,000	1,567,500	35
	1,568,000	35
	1,568,500	21
	1,569,000	11
	1,569,500	- 2 2/
	1,570,000	0
728,500	1,567,500	37
	1,568,000	42
	1,568,500	43
	1,569,000	40
	1,569,500	- 5 2/
729,000	1,567,500	-25 2/
	1,568,000	36
	1,568,500	35
	1,569,000	3
729,500	1,568,000	16
	1,568,500	30
730,000	1,568,000	21
	1,568,500	35

1/ Depths represent deposited materials as of survey dated September 1980.
2/ Negative numbers show erosion below that of the finish grade after construction.

Table 6

DIMENSIONLESS RECHARGE RATES FOR PRE-PROJECT AND POST-PROJECT CONDITIONS

Node	Condition						
	"0"	"1"	"2"	"3"	"4"	"5.0"	"5"
Reservoir Area							
107	1.0	0.100	0.100	0.010	0.200	0.005	0.004
108	1.0	0.100	0.100	0.010	0.200	0.005	0.004
123	1.0	0.450	0.200	0.010	0.200	0.005	0.004
124	1.0	0.850	0.400	0.075	0.100	0.075	0.075
132	1.0	1.000	1.000	1.000	1.000	1.000	1.000
Existing Spreading Basins							
133	1.0	0.070	0.970	0.050	0.050	0.900	0.900
140	1.0	1.000	1.000	1.000	1.000	1.000	1.000
141	1.0	0.970	0.950	0.970	1.000	0.900	0.900
155	1.0	1.000	0.900	0.975	1.000	0.900	0.900

Note: For a definition of various representative hydrologic and watershed conditions, see paragraph 3.b.(3).

Table 7

Estimated Sediment Production Rates for Watersheds Contributing Sediment
To The Proposed Mentone Dam Site Under Current Forest and Watershed Conditions

Watershed (2)	PWI Number (2)	70-yr Mean Ann.Prec. (inches)	Area of Watershed (sq.mi.)	Watershed Burn Hist. (Fire yr/ Est%of wtrshd brnd) (2)	Adjsted Burn Factor To Acct for Current Fire Damage (Dimensionless) (3)	Est Ave Ann Sed Prod for Normal Wtrshd Conditions (cu.yds sq.mi/ yr.)x10 (4)	Ave Ann Sed Prod Adjsted for Crrnt Burn Conditions (cu.yds/yr)x10 (5)	Adjsted Ave Ann Yield to Mentone Dam Site AF/sq.mi/yr
Big Bear Lake	23	24.8	38 (8)	1973/02	2.4	0.42	16.41 (8)	0.27 (8)
Santa Ana River	22	32.9	140.0	1970/85.1979/05	1.0,4.4	1.39	227.68	1.01
Plunge Creek	25	34.8	16.9	1970/90	1.0	3.64	61.52	2.26
Mill Creek	20	34.1	43.2	1970/10	1.0	1.42	61.34	0.88
Morton Canyon	21	21.9	2.5	1979/60	7.9	3.60	46.26	11.47
Mill Creek Wash	19	21.8	4.3	1970/75.1979/10	7.2	3.78	26.32	3.80
Oak Creek	24	22.9	3.7	1970/35.1979/10	6.8	1.75	10.23	1.71
			210.6 (8) (sq.mi.)				(8) 433.36x10^3 (cu.yds./yr)	(8) 1.28 AF mi 2

(1) Estimated values presented herein have been developed for current forest and watershed conditions and reflect effects due to past forest fires.

(2) From San Bernardino National Forest Service fire history maps.

(3) The Burn factor (dimensionless) represents the increased relative magnitude in sediment production for a specific watershed based on the number of recovery years since the last fire occurred. Normal forest conditions are assumed after 10 years of recovery time.

(4) Amount of sediment production that would be produced if the entire forest and watershed were unaffected by previous fire damage.

(5) Adjusted sediment production to reflect increasd sediment production rates from fire-damage watersheds.

(6) Assumes that the average dry density of the material is 95 lbs/ft.^{3}

(7) Although dischargeing flows from Big Bear Lake contribute to the total flow entering the Santa Ana River,it is assumed that all of the sediment produced from the Big Bear Lake watershed is trapped in the lake. Therefore,sediment production and yield from the Big Bear Lake Watershed were not included in the totals or basin average.

Table 8

Estimated Sediment Production for Reasonable Maximum Burn Conditions Due to Average Annual Precipitation Occurring on All Watersheds With Less Than One Year of Reforestration Recovery Time

Watershed	Area (mi2)	Assumed Reasonable Max.Burn Conditions	Adjusted Burn Factor	100% Burn Sedt. Production Rate (cu.yd/sq.mi/yr)x10^3	Reasonable Max.Sedmt Prod. (with ≤1 year Recovery Time) (cu yds/yr)x10^3	Adjstd Rsnble Max Sed Yield (AF/sq.mi/yr)
Santa Ana	140	1982/50	18	25.02	1848.7	8.2
Plunge Creek	16.9	1982/100	29.6	106.47	1833.14	67.2
Mill Creek	43.2	1982/50	21.4	30.39	687.1	9.9
Morton Canyon	2.5	1982/100	35	126.0	315.	78.1
Mill Creek Wash	4.3	1982/100	32.1	119.45	513.64	74.0
Oak Creek	3.7	1982/100	29.8	52.15	192.96	32.3
	210.6 sq. mi.				5.39x10^6 cu yds/yr	15.9 AF/mi ^{2}

Table 9

Estimated SPF Sediment Production

Watershed	Drainage Area (mi2)	Current Watershed Burn Conditions (yd^3/STORM)x10^6	Estimated Current Watershed Burn Conditions (Fire yr./%Burned)	Reasonable Maximum Burn Conditions (yd^3/STORM)x10^6	Assumed Reasonable Maximum Burn Conditions (Fire yr./%Burned)
Santa Ana	140.0	1.233	1970/45, 1979/05	8.366	1982/50
Plunge Creek	16.9	0.220	1970/90	2.197	1982/100
Mill Creek	43.2	0.320	1970/10	2.732	1982/50
Morton Canyon	2.5	0.129	1979/60	0.330	1982/100
Mill Creek Wash	4.3	0.076	1970/75, 1979/10	0.546	1982/100
Oak Creek	3.7	0.048	1970/35, 1979/10	0.538	1982/110
	210.6 mi 2	2.026×10^6 yd^3 STORM 1256 AF / STORM		14.709×10^6 yd^3 STORM 9117 AF / STORM	

Average SPF Sediment Yield for Current Burn Conditions

5.96 AF / sq.mi. / STORM

Average SPF Sediment Yield for Reasonable Maximum Burn Conditions

43.3 AF / sq.mi./STORM

Table 10

Simulated Depths of Deposited Sediment for
Various Hydrologic Events and Watershed Conditions

Description of Hydrologic Event and Watershed Conditions	Distance from Dam (feet) 1400	1800	2200	2600	3000	4000	5000	6000	7000	7830	8180	8530	Total Vol. of Deposit (ac. ft.)
	Depths in Feet												
Mean Annual Flood, Current Burn	0.31	0.34	0.59	1.98	0.06	0.08	0	0	0	0	0	0	280
Mean Annual Flood, Reasonable Maximum Burn (One Time Event)	2.95	3.05	4.79	15.25	9.23	0.13	0.08	0.02	0.01	0	0	0	3,330
Standard Project Flood, Current Burn	0.41	0.34	0.39	0.42	0.62	1.16	1.24	2.61	1.90	0.54	0.85	0.44	1,260
Standard Project Flood Reasonable Maximum Burn (One Time Event)	5.10	4.30	4.93	4.94	5.53	6.80	7.28	9.67	7.34	4.36	5.67	4.59	9,150
Fifty Years of Mean Annual Events Under Current Burn Conditions	6.48	6.37	8.44	12.85	29.73	34.16	10.34	0	0	0	0	0	15,250
100 Yrs. of Mean Annual Events Under Current Burn Conditions (Extrapolated)	10.50	11.80	12.25	25.3	48.00	53.0	36.00	0	0	0	0	0	24,780

Table 11

Summary of Recharge Redistribution
Conditions 3 - SPF, Current Burn

Water Year	Total Calibrated Recharge	Potential Loss in Recharge	Nodes Downstream of Mentone Damsite 89	102	103	104	105	115	122	Nodes Upstream of Mentone Damsite 132	133	154	156	157	158	159	Totals
1946	184	2.77	1.14	.51	.51	.51	.51	1.14	4.18	.37	.35	.17	4.38	1.41	4.38	3.24	22.80
47	180	2.73	1.12	.49	.49	.49	.49	1.12	4.16	.36	.34	.17	4.37	1.40	3.70	3.40	22.10
48	125	1.90	.78	.34	.34	.34	.34	.78	2.91	.25	.24	.12	2.94	.98	2.52	2.56	15.44
49	105	1.62	.65	.29	.29	.29	.29	.65	2.47	.21	.20	.10	2.51	.83	2.15	2.03	12.96
1940	120	1.87	.75	.34	.34	.34	.34	.75	2.61	.24	.23	.12	2.93	.97	2.52	2.37	14.85
51	86	1.36	.53	.24	.24	.24	.24	.53	2.05	.17	.16	.09	2.10	1.44	1.80	1.70	11.53
52	83	1.28	.51	.23	.23	.23	.23	.51	2.03	.16	.15	.08	2.07	1.41	1.77	1.67	11.28
53	183	2.90	1.14	.51	.51	.51	.51	1.14	3.65	.37	.35	.18	4.58	1.50	3.92	3.70	22.57
54	78	1.28	.49	.22	.22	.22	.22	.49	1.82	.16	.15	.08	2.07	.67	.177	1.67	10.25
55	142	2.32	.90	.41	.41	.41	.41	.90	3.29	.29	.28	.15	3.74	1.22	3.20	3.02	18.63
56	92	1.51	.59	.27	.27	.27	.27	.59	2.19	.18	.17	.09	2.46	.78	2.10	1.98	12.21
57	78	1.28	.50	.23	.23	.23	.23	.50	1.93	.16	.15	.08	2.07	.67	1.77	1.67	10.42
58	88	1.38	.55	.25	.25	.25	.25	.55	2.07	.18	.17	.09	2.11	.71	1.81	1.71	10.95
59	261	3.91	1.55	.65	.65	.65	.65	1.55	5.54	.52	.49	.08	5.50	1.58	4.66	4.38	28.45
1960	81	1.28	.51	.23	.23	.23	.23	.51	1.94	.16	.15	.08	2.07	.67	1.77	1.67	10.45
61	82	1.28	.51	.23	.23	.23	.23	.51	1.94	.16	.15	.08	2.07	.67	1.77	1.67	10.45
62	49	.99	.33	.17	.17	.17	.17	.33	1.36	.19	.18	.06	1.36	.52	1.09	1.03	7.13
63	121	1.87	.76	.34	.34	.34	.34	.76	3.16	.124	.23	.12	2.73	.97	2.51	2.37	15.21
64	66	1.04	.42	.19	.19	.19	.19	.42	1.79	.13	.12	.07	1.67	.55	1.43	1.35	8.71
65	74	1.11	.46	.20	.20	.20	.20	.46	2.53	.15	.14	.07	1.69	.57	1.45	1.37	9.69
66	161	2.46	1.00	.44	.44	.44	.44	1.00	4.08	.32	.30	.15	3.77	1.25	3.23	3.05	19.91
67	217	2.75	.93	.47	.47	.47	.47	.93	5.35	.27	.26	.17	5.16	1.52	4.38	4.12	24.97
68	201	3.15	1.26	.57	.57	.57	.57	1.26	5.66	.40	.38	.21	5.00	1.64	4.28	4.04	26.41
69	243	2.72	1.37	.53	.53	.53	.53	1.37	5.06	.49	.47	.17	2.93	1.25	2.57	2.45	20.25
1970	361	5.48	1.95	.71	.71	.71	.71	1.95	10.35	.72	.68	.40	8.12	2.52	6.92	6.52	42.97
71	127	2.05	.80	.36	.36	.36	.36	.80	4.41	.25	.24	.13	3.31	1.07	2.83	2.67	17.95
72	111	1.66	.69	.30	.30	.30	.30	.69	3.60	.22	.21	.10	2.52	.84	2.16	2.04	14.27
73	105	1.49	.63	.27	.27	.27	.27	.63	3.37	.21	.20	.09	2.14	.74	1.84	1.74	12.67
74	256	3.47	1.53	.65	.65	.65	.65	1.53	5.08	.51	.48	.22	4.80	1.72	4.14	3.92	26.53
75	134	2.11	.84	.38	.38	.38	.38	.84	2.37	.27	.26	.13	3.33	1.19	2.85	2.69	16.29
76	152	7.37	1.01	.59	.81	1.47	4.13	3.83	2.50	11.70	10.17	2.78	6.74	6.74	6.74	6.74	65.95
77	236	11.11	1.45	.64	3.24	3.24	7.38	4.95	6.03	16.20	13.82	3.73	8.30	8.30	8.30	8.30	93.88
78	180	3.73	1.22	.60	1.54	1.50	1.60	2.21	4.27	5.63	4.72	2.14	3.94	3.94	3.94	3.94	41.19
79	640	48.62	3.07	.87	14.87	14.87	29.83	13.45	10.88	55.42	45.83	9.18	23.39	29.39	23.39	23.39	291.83
1980	415	27.27	2.17	.74	8.29	8.29	16.61	9.74	8.05	33.22	28.84	6.35	15.45	15.45	15.45	15.45	183.60
81	430	28.41	2.23	.75	8.57	8.57	16.23	9.72	9.32	34.64	29.56	6.64	16.12	16.12	16.12	16.12	190.71
Totals	6247	189.53	36.34	15.21	48.34	48.96	86.80	69.09	144.00	165.12	140.32	34.67	170.44	107.20	157.23	151.74	1375.46

Note: All values expressed in cubic feet per second (cfs).

Table 12

Summary of Recharge Redistribution
Conditions 5.0 - MAF, 50 Year Simulation

Water	Total Calibrated	Potential Loss in	Nodes Downstream of Mentone Damsite							Nodes Upstream of Mentone Damsite							
Year	Recharge	Recharge	89	102	103	104	105	115	122	132	133	154	156	157	158	159	Totals
1946	184	2.85	1.15	.52	.52	.52	.52	1.15	4.19	.37	.33	.17	4.21	1.41	4.21	3.41	22.68
47	180	2.82	1.13	.50	.50	.50	.50	1.13	4.17	.36	.32	.17	4.20	1.40	3.60	3.40	21.88
48	125	2.64	.89	.45	.45	.45	.45	.89	3.02	.25	.22	.16	3.02	1.06	2.60	2.46	16.37
49	105	1.66	.66	.30	.30	.30	.30	.66	2.48	.21	.19	.10	2.51	.83	2.15	2.03	13.02
1950	120	1.92	.74	.34	.34	.34	.34	.75	2.61	.24	.22	.11	2.91	.95	2.50	2.35	14.75
51	86	1.39	.54	.25	.25	.25	.25	.54	2.06	.17	.15	.08	2.08	1.42	1.78	1.68	11.50
52	83	1.33	.52	.24	.24	.24	.24	.52	2.04	.16	.14	.08	2.05	1.41	1.77	1.67	11.32
53	173	2.88	1.16	.53	.53	.53	.53	1.16	3.67	.37	.33	.18	4.58	1.50	3.92	3.70	22.69
54	78	1.33	.50	.23	.23	.23	.23	.50	1.83	.16	.14	.08	2.07	.67	.177	1.67	10.31
55	142	2.40	.86	.37	.37	.37	.37	.86	3.25	.29	.26	.14	2.72	1.20	3.18	3.00	17.24
56	92	1.54	.59	.27	.27	.27	.27	.59	2.19	.18	.16	.09	2.46	.78	2.10	1.98	12.20
57	78	1.33	.51	.24	.24	.24	.24	.51	1.94	.16	.14	.08	2.07	.67	1.77	1.67	10.48
58	88	1.41	.51	.21	.21	.21	.21	.51	2.03	.18	.16	.08	2.09	.69	1.79	1.69	10.57
59	261	4.02	1.55	.65	.65	.65	.65	1.55	5.54	.52	.47	.10	5.52	1.60	4.68	4.40	28.53
1960	81	1.33	.52	.24	.24	.24	.24	.52	1.95	.16	.14	.08	2.07	.67	1.77	1.67	10.51
61	82	1.33	.52	.24	.24	.24	.24	.52	1.95	.16	.14	.08	2.07	.67	1.77	1.67	10.51
62	49	1.02	.34	.18	.18	.18	.18	.34	1.37	.19	.17	.06	1.36	.52	1.09	1.03	7.19
63	121	1.92	.76	.34	.34	.34	.34	.76	3.16	.24	.22	.11	2.71	.95	2.49	2.35	15.11
64	66	1.07	.42	.19	.19	.19	.19	.42	1.79	.13	.12	.06	1.65	.53	1.41	1.33	8.62
65	74	1.16	.47	.21	.21	.21	.21	.47	2.54	.15	.14	.07	1.69	.57	.145	.137	9.76
66	161	2.53	1.01	.45	.45	.45	.45	1.01	4.09	.32	.29	.15	3.77	1.25	3.23	3.03	19.95
67	217	2.83	.94	.48	.48	.48	.48	.94	5.36	.27	.24	.17	5.16	1.52	4.38	4.12	25.02
68	201	3.25	1.27	.58	.58	.58	.58	1.27	5.67	.40	.36	.19	4.98	1.62	4.26	4.02	26.36
69	243	2.85	1.39	.55	.55	.55	.55	1.39	5.08	.49	.44	.17	2.93	1.25	2.57	2.45	20.36
1970	361	5.64	1.95	.71	.71	.71	.71	1.95	10.35	.72	.65	.43	.15	2.55	6.95	6.55	43.09
71	127	2.10	.81	.37	.37	.37	.37	.81	4.42	.25	.22	.12	3.29	1.05	2.81	2.65	17.91
72	111	1.71	.69	.30	.30	.30	.30	.69	3.60	.22	.20	.10	2.52	.84	.216	2.04	14.26
73	105	1.43	.64	.28	.28	.28	.28	.64	3.38	.21	.19	.09	2.14	.74	1.84	1.74	12.73
74	256	3.58	1.53	.65	.65	.65	.65	1.53	5.08	.51	.46	.02	4.38	1.70	3.72	3.50	25.03
75	134	2.18	.84	.39	.39	.39	.39	.85	2.38	.27	.24	.13	3.33	1.19	2.85	2.69	16.34
76	152	8.30	1.01	.59	.81	1.47	4.13	3.83	2.50	12.85	10.32	2.91	6.87	6.87	6.87	6.87	67.90
77	236	12.64	1.45	.64	3.24	3.24	7.38	4.95	6.03	16.42	14.04	3.94	8.51	8.51	8.51	8.51	95.37
78	180	4.03	1.22	.60	1.54	1.50	1.60	2.21	4.27	5.67	4.76	2.18	3.98	3.98	3.98	3.98	41.47
79	640	51.77	3.07	.87	14.87	14.87	29.83	13.45	10.88	54.89	46.30	9.63	23.83	23.83	23.83	23.83	293.98
1980	415	30.81	217	.74	8.29	8.29	16.61	9.74	8.05	33.76	28.88	6.85	15.95	15.95	15.95	15.95	187.18
81	430	32.13	2.23	.75	8.57	8.57	16.23	9.72	9.82	34.25	30.17	7.20	16.69	16.69	16.69	16.69	193.77
Totals	6247	205.23	36.50	15.45	48.58	49.20	87.04	69.33	144.24	166.15	141.92	36.36	170.52	109.04	158.40	153.15	1385.96

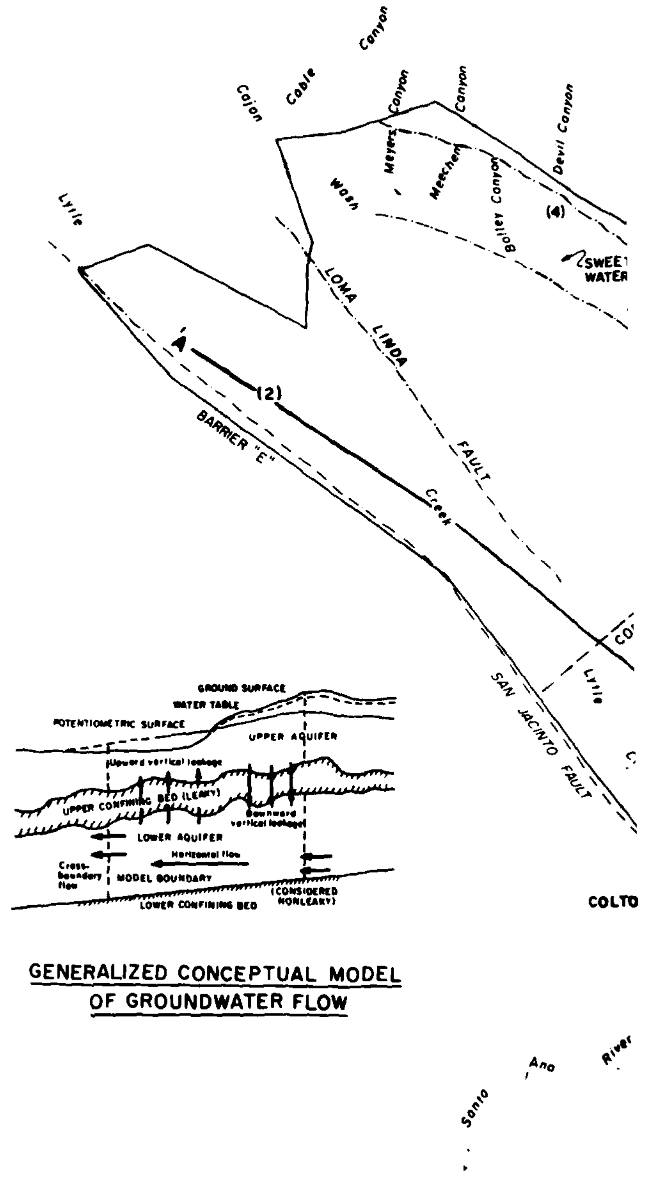
Note: All values expressed in cubic feet per second (cfs).

Table 13

Summary of Recharge Redistribution
Conditions 5.1 - MAF, 100 Year Simulation

Water Year	Total Calibrated Recharge	Potential Loss in Recharge	Nodes Downstream of Mentone Damsite									Nodes Upstream of Mentone Damsite					Totals
			89	102	103	104	105	115	122	132	133	154	156	157	158	159	
1946	184	2.89	1.15	.52	.52	.52	.52	1.15	4.19	.37	.33	.17	4.21	1.41	4.21	3.41	22.68
47	180	2.86	1.14	.51	.51	.51	.51	1.14	4.18	.36	.32	.17	4.20	1.40	4.20	3.40	22.55
48	125	1.97	.79	.35	.35	.35	.35	.79	2.92	.25	.23	.12	2.94	.98	2.52	2.38	14.32
49	105	1.68	.66	.30	.30	.30	.30	.66	2.48	.21	.19	.10	2.51	.83	2.15	2.03	13.02
1950	120	1.93	.76	.35	.35	.35	.35	.76	2.62	.24	.22	.12	2.93	.97	2.52	2.37	14.91
51	86	1.39	.54	.25	.25	.25	.25	.54	2.06	.17	.15	.08	2.08	1.42	1.78	1.68	11.50
52	83	1.35	.52	.24	.24	.24	.24	.52	2.04	.16	.14	.08	2.07	1.41	1.77	1.67	11.34
53	183	2.96	1.15	.52	.52	.52	.52	1.15	3.66	.37	.33	.17	4.56	1.48	3.90	3.68	22.53
54	78	1.35	.50	.23	.23	.23	.23	.50	1.83	.16	.14	.08	2.07	.67	1.77	1.67	10.31
55	142	2.41	.91	.42	.42	.42	.42	.91	3.30	.29	.26	.14	3.72	1.18	3.18	3.00	18.57
56	92	1.56	.59	.27	.27	.27	.27	.59	2.19	.18	.16	.09	2.46	.78	2.10	1.98	12.20
57	78	1.32	.51	.23	.23	.23	.23	.51	1.94	.16	.15	.08	2.07	.67	1.77	1.67	10.45
58	88	1.43	.55	.25	.25	.25	.25	.55	2.07	.18	.16	.08	2.09	.69	1.79	1.69	10.85
59	261	4.04	1.55	.65	.65	.65	.65	1.55	5.54	.52	.47	.11	5.53	1.61	4.69	4.41	28.58
1960	81	1.32	.52	.24	.24	.24	.24	.52	1.95	.16	.15	.08	2.07	.67	1.77	1.67	10.52
61	82	1.32	.52	.24	.24	.24	.24	.52	1.95	.16	.15	.08	2.07	.67	1.77	1.67	10.52
62	49	1.03	.34	.18	.18	.18	.18	.34	1.37	.19	.17	.06	1.36	.52	1.09	1.03	7.19
63	121	1.93	.77	.35	.35	.35	.35	.77	3.17	.24	.22	.11	2.71	.95	.249	2.35	15.18
64	66	1.07	.42	.19	.19	.19	.19	.42	1.79	.13	.12	.06	1.65	.53	1.41	1.33	8.62
65	74	1.15	.46	.20	.20	.20	.20	.46	2.53	.15	.14	.07	1.69	.57	1.45	1.37	9.69
66	161	2.54	1.01	.45	.45	.45	.45	1.01	4.09	.32	.29	.15	3.77	1.25	3.23	3.05	19.97
67	217	2.85	.95	.49	.49	.49	.49	.95	5.37	.27	.24	.17	4.17	1.52	4.38	4.12	25.10
68	201	3.27	1.28	.59	.59	.59	.59	1.28	5.68	.40	.36	.19	4.98	1.62	4.26	4.02	26.43
69	243	2.89	1.39	.55	.55	.55	.55	1.39	5.08	.49	.44	.17	2.93	1.25	2.57	2.45	20.36
1970	361	5.68	1.95	.71	.71	.71	.71	1.95	10.35	.72	.65	.44	8.16	2.56	6.96	6.56	43.14
71	127	2.10	.81	.37	.37	.37	.37	.81	4.42	.25	.23	.12	3.29	1.05	2.81	2.65	17.92
72	111	1.72	.70	.31	.31	.31	.31	.70	3.61	.22	.20	.10	2.52	.84	2.16	2.04	14.33
73	105	1.55	.64	.28	.28	.28	.28	.64	3.38	.21	.19	.09	2.14	.74	1.84	1.74	12.73
74	256	3.61	1.53	.65	.65	.65	.65	1.53	5.08	.51	.46	.02	4.38	1.30	3.72	3.50	24.63
75	134	2.21	.86	.40	.40	.40	.40	.86	2.39	.27	.24	.13	3.33	1.16	2.85	2.69	16.38
76	152	8.33	1.01	.59	.81	1.47	4.13	3.83	2.50	11.84	10.31	2.92	6.88	6.88	6.88	6.88	66.93
77	236	12.69	1.45	.64	3.24	3.24	7.38	4.95	6.03	16.42	14.04	3.95	8.51	8.51	8.51	8.51	95.38
78	180	4.07	1.22	.60	1.54	1.50	1.60	2.21	4.27	5.67	4.76	2.18	3.98	3.98	3.98	3.98	41.47
79	640	51.90	3.07	.87	14.87	14.87	29.83	13.45	10.88	54.92	46.33	9.65	23.85	23.85	23.85	23.85	294.14
1980	415	30.96	2.17	.74	8.29	8.29	16.61	9.74	8.05	33.78	28.90	6.87	15.97	15.97	15.97	15.97	187.32
81	430	32.22	2.23	.75	8.57	8.57	16.23	9.72	9.32	35.21	30.13	7.17	16.65	16.65	16.65	16.65	194.50
Totals	6247	205.55	36.62	15.48	48.61	49.23	87.07	69.37	144.28	166.15	141.97	36.27	17.50	108.54	158.95	153.12	1387.26

Note: All values expressed in cubic feet per second (cfs).



GENERALIZED CONCEPTUAL MODEL OF GROUNDWATER FLOW

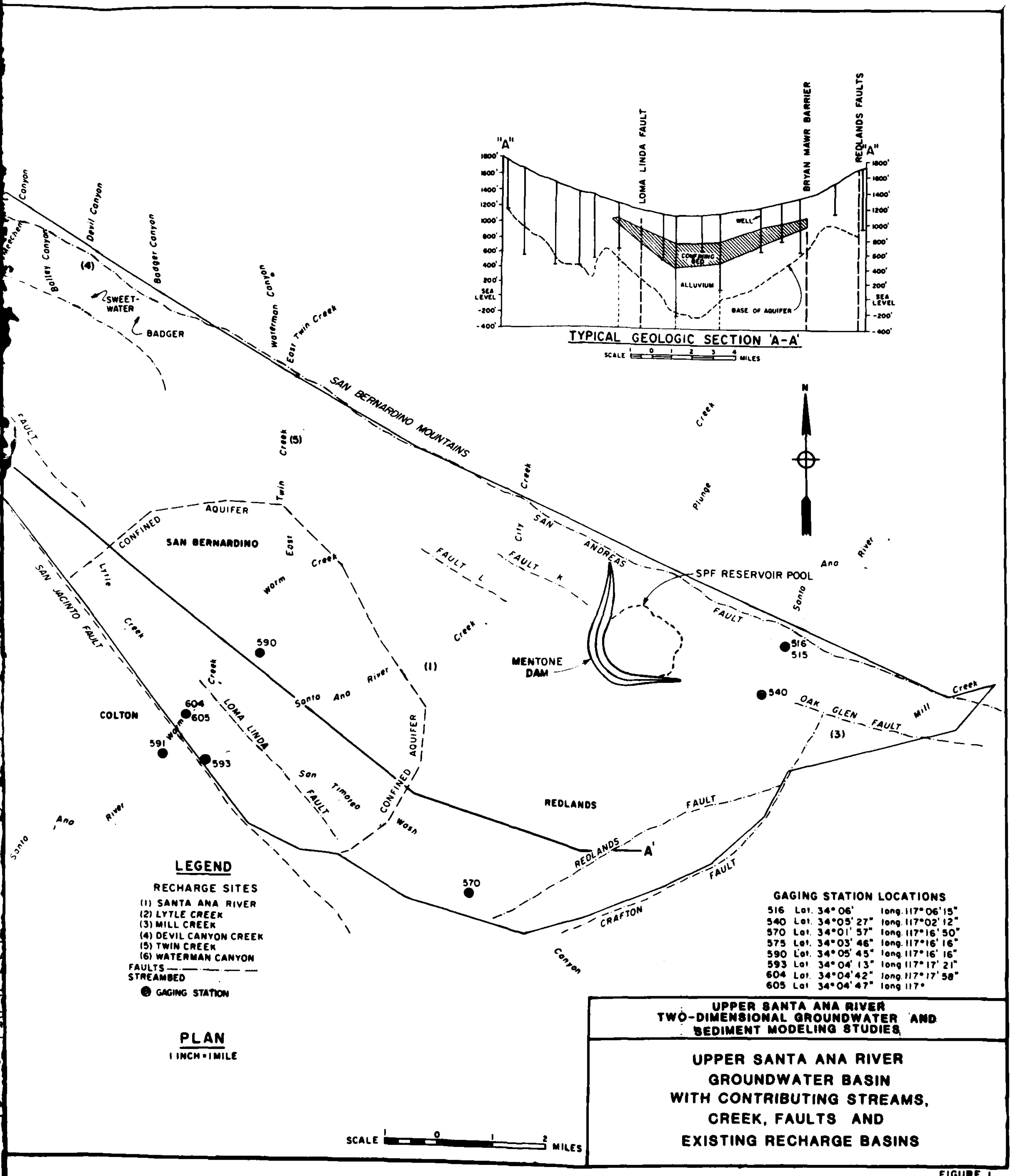
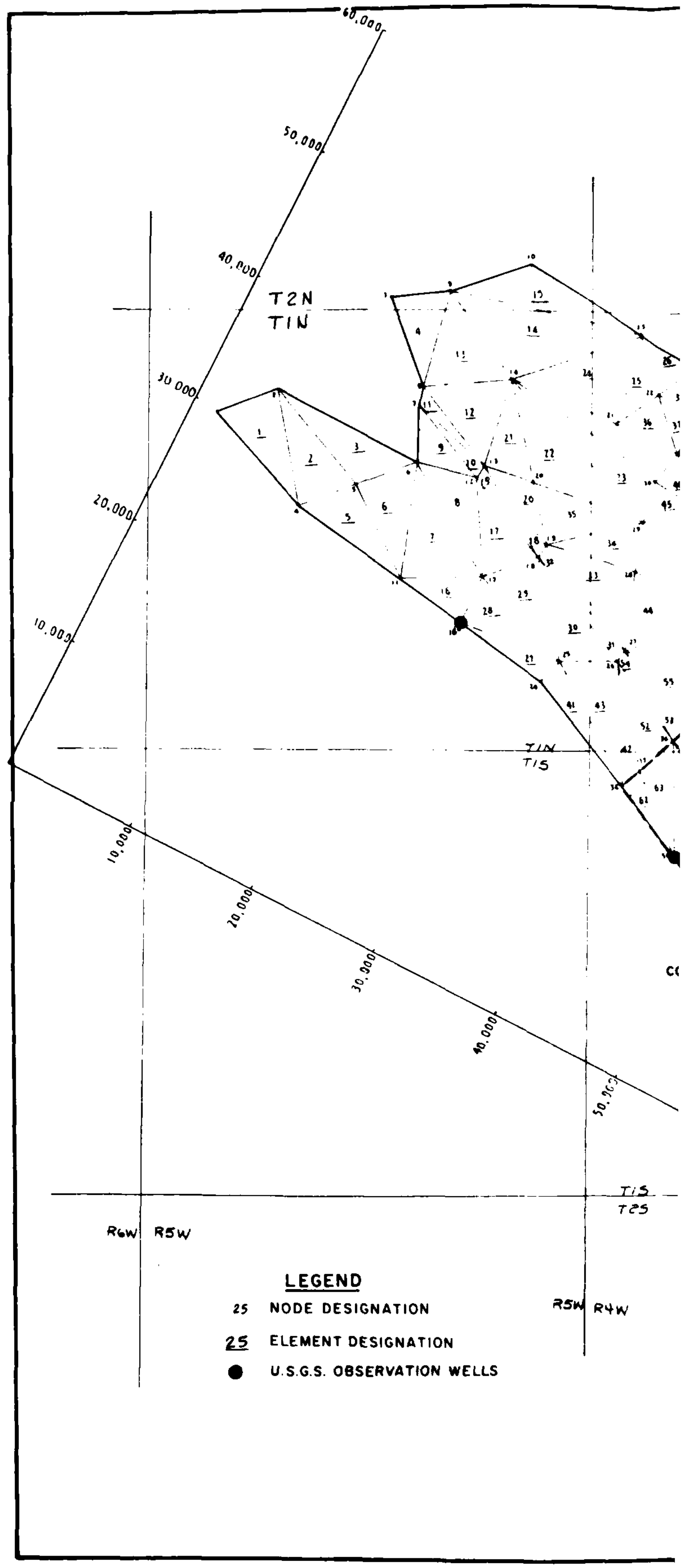
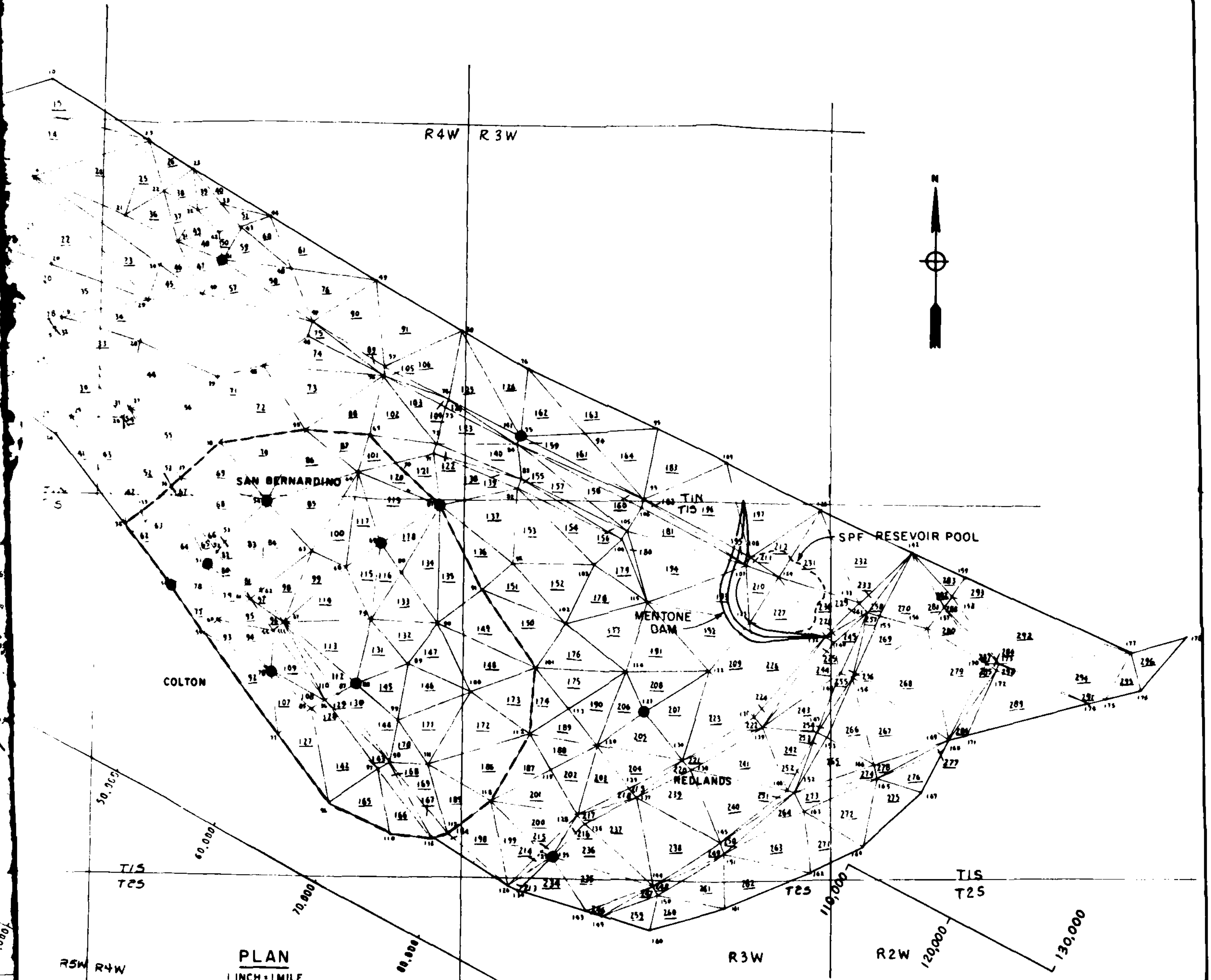

TYPICAL GEOLOGIC SECTION 'A-A'
"A"
"A'"
LOMA LINDA FAULT
BRYAN MAWR BARRIER
REDLANDS FAULTS
WELL
CONFINING BED
ALLUVIUM
BASE OF AQUIFER
SEA LEVEL
1800'
1600'
1400'
1200'
1000'
800'
600'
400'
200'
-200'
-400'
SCALE 1 0 1 2 3 4 MILES
N
SAN BERNARDINO MOUNTAINS
SAN ANDREAS FAULT
SAN JACINTO FAULT
LOMA LINDA FAULT
REDLANDS FAULT
CRAFTON FAULT
OAK GLEN FAULT
FAULT L
FAULT K
CONFINED AQUIFER
SAN BERNARDINO
COLTON
REDLANDS
MENTONE DAM
SPF RESERVOIR POOL
SWEET-WATER
BADGER
Devil Canyon
Badger Canyon
Bailey Canyon
Meechem
Waterman Canyon
East Twin Creek
Twin Creek
East Twin Creek
Lytle Creek
Warm Creek
City Creek
Plunge Creek
Mill Creek
Santa Ana River
San Timoteo Wash
Crafton Canyon
(1)
(3)
(4)
(5)
516
515
540
570
590
591
593
604
605
A'
LEGEND
RECHARGE SITES
(1) SANTA ANA RIVER
(2) LYTLE CREEK
(3) MILL CREEK
(4) DEVIL CANYON CREEK
(5) TWIN CREEK
(6) WATERMAN CANYON
FAULTS
STREAMBED
GAGING STATION
PLAN
1 INCH = 1 MILE
GAGING STATION LOCATIONS
516 Lat. 34° 06' long. 117° 06' 15"
540 Lat. 34° 05' 27" long. 117° 02' 12"
570 Lat. 34° 01' 57" long. 117° 16' 50"
575 Lat. 34° 03' 46" long. 117° 16' 16"
590 Lat. 34° 05' 45" long. 117° 16' 16"
593 Lat. 34° 04' 13" long 117° 17' 21"
604 Lat. 34° 04' 42" long. 117° 17' 58"
605 Lat 34° 04' 47" long 117°
SCALE 1 0 1 2 MILES
UPPER SANTA ANA RIVER
TWO-DIMENSIONAL GROUNDWATER AND SEDIMENT MODELING STUDIES
UPPER SANTA ANA RIVER GROUNDWATER BASIN WITH CONTRIBUTING STREAMS, CREEK, FAULTS AND EXISTING RECHARGE BASINS

FIGURE 1



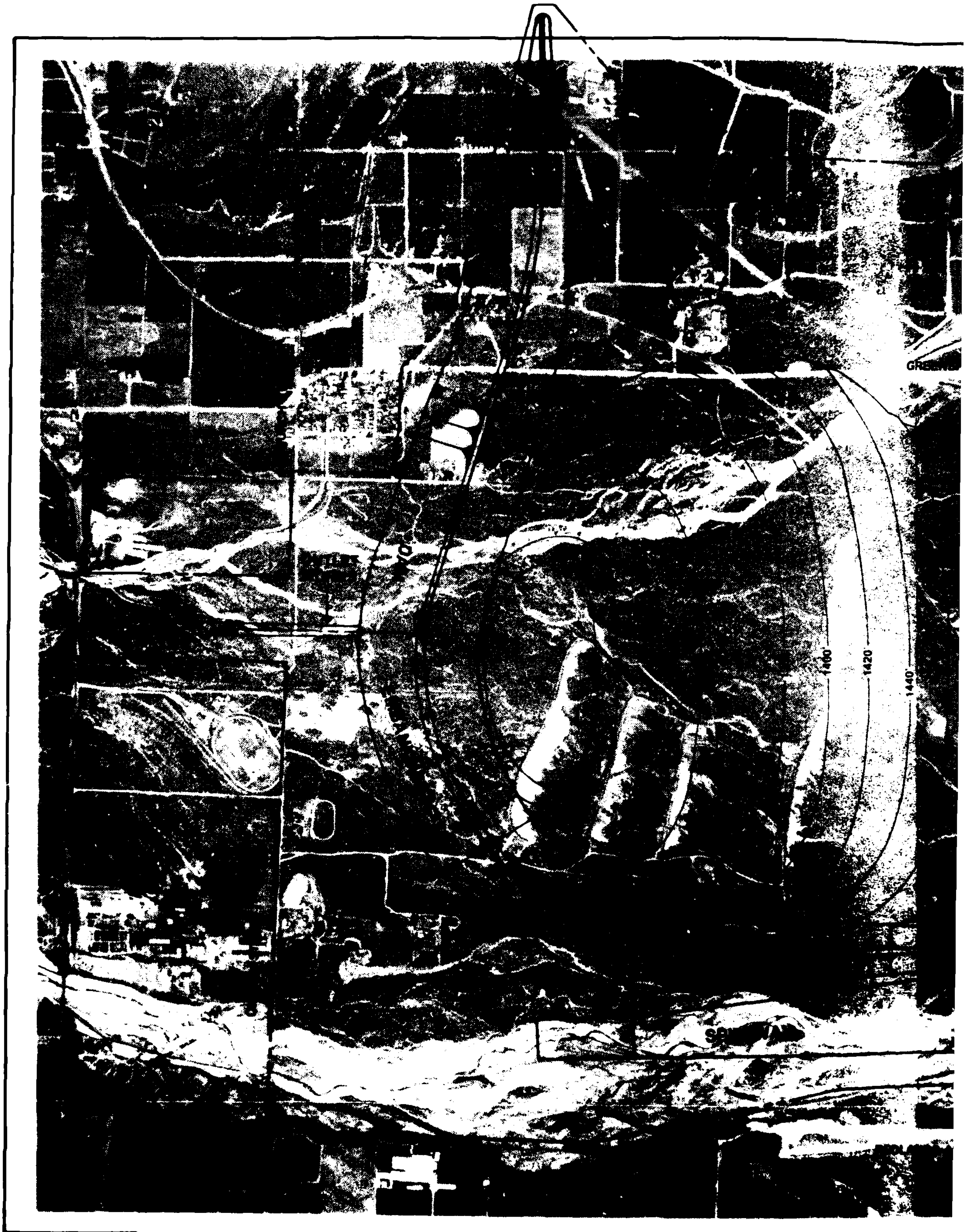
T2N
T1N
T1N
T1S
T1S
T2S
R6W R5W
R5W R4W
LEGEND
25 NODE DESIGNATION
25 ELEMENT DESIGNATION
U.S.G.S. OBSERVATION WELLS



UPPER SANTA ANA RIVER
TWO-DIMENSIONAL GROUND WATER AND
SEDIMENT MODELING STUDIES

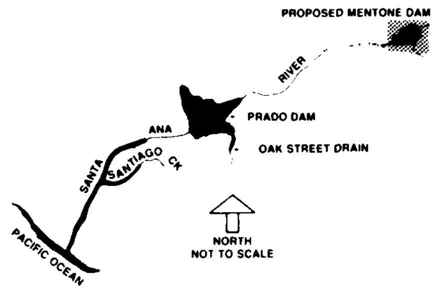
NODAL NETWORK OF GROUNDWATER SIMULATION
DOMAIN INCLUDING EXISTING
U.S.G.S. OBSERVATION WELLS

FIGURE 2


1400
1420
1440

PROPOSED MILL
LEVEE
ANA
RIVER
MILL
CREEK

KEY



LEGEND

— — — — PROJECT RIGHT OF WAY

—1335— TO —1540— FINISH CONTOUR LINES

SCALE

1000′ 0 1000′

UPPER SANTA ANA RIVER BASIN
TWO DIMENSIONAL GROUNDWATER
AND SEDIMENT MODELING STUDIES

GENERAL PLAN
MENTONE DAM

FIGURE 3

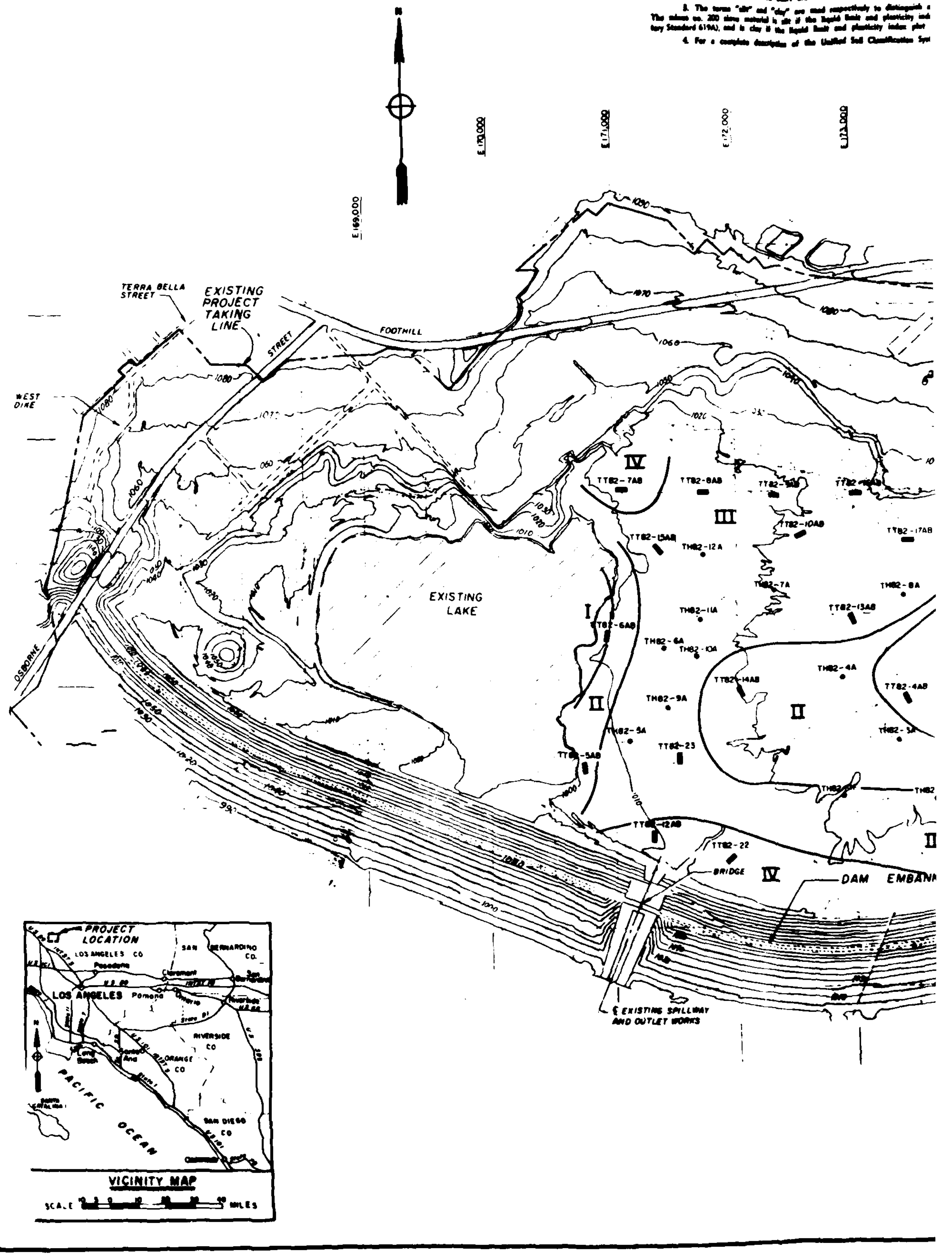
NOTES:

1. Boundary Classification: Soils possessing characteristics of two gro
GW-GC, well-graded gravel-sand mixture with clay binder.

2. All sieve sizes on this chart are U. S. Standard.

3. The terms "silt" and "clay" are used respectively to distinguish
The minus no. 200 sieve material is silt if the liquid limit and plasticity ind
tory Standard 619A), and is clay if the liquid limit and plasticity index plot

4. For a complete description of the Unified Soil Classification Sys



NOTES:

1. Secondary Classification: Soils possessing characteristics of two groups are designated by combinations of group symbols. For example, GW-GC, well-graded gravel-sand mixture with clay binder.

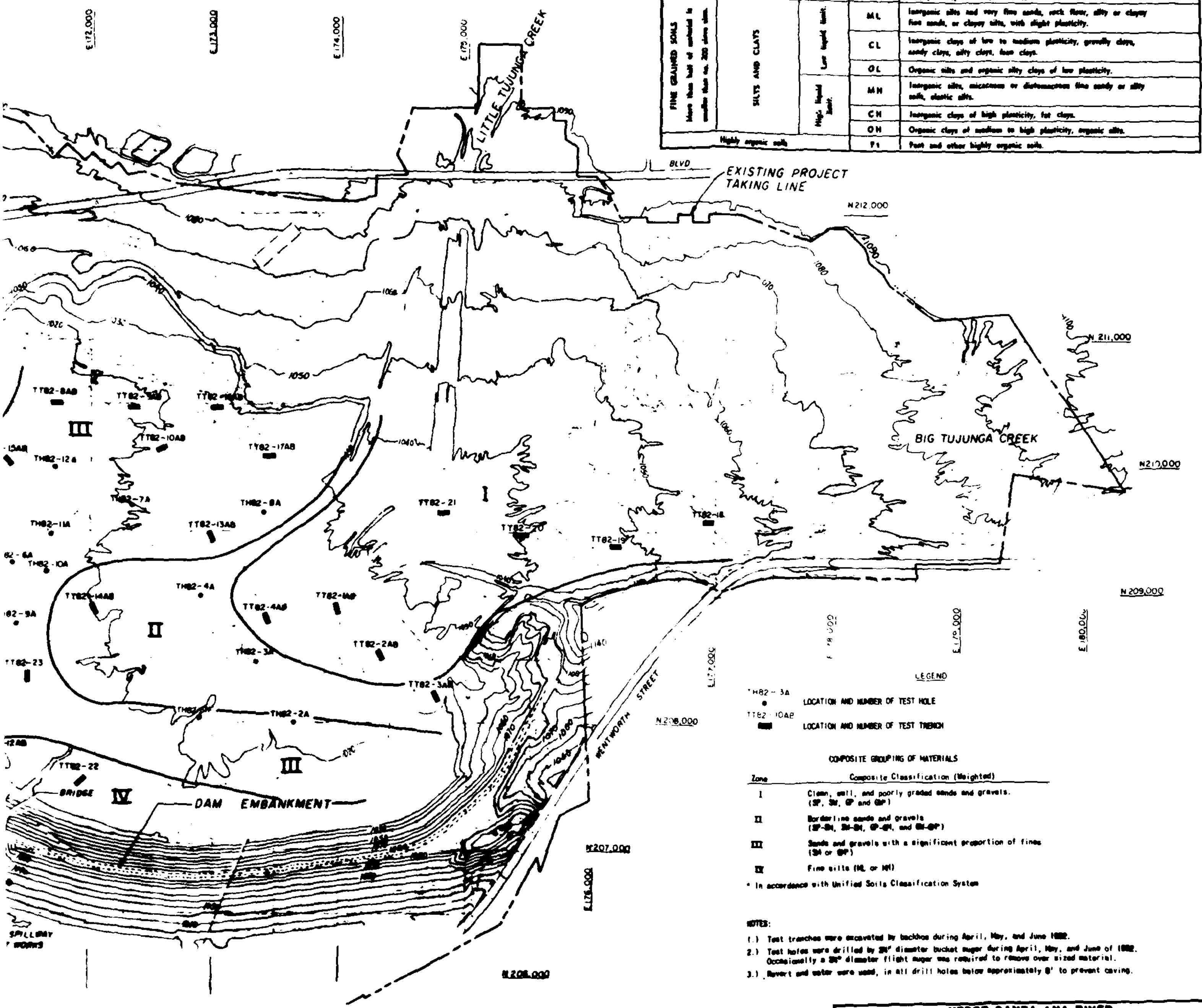
2. All sieve sizes on this chart are U. S. Standard.

3. The terms "silt" and "clay" are used respectively to distinguish materials exhibiting lower plasticity from those with higher plasticity. The minus no. 200 sieve material is silt if the liquid limit and plasticity index plot below the "A" line on the plasticity chart (Table VI, Military Standard 619A), and is clay if the liquid limit and plasticity index plot above the "A" line on the chart.

4. For a complete description of the Unified Soil Classification System, see "Military Standard 619A" dated 20 March 1976.

UNIFIED SOIL CLASSIFICATION SYSTEM

MAJOR DIVISIONS			GROUP SYMBOLS	TYPICAL NAMES
COARSE GRAINED SOILS More than half of material is larger than no. 200 sieve size.	GRAVELS More than half of coarse fraction is larger than no. 4 sieve size.	Clean gravels	GW	Well-graded gravels, gravel-sand mixtures, little or no fines.
			GP	Poorly-graded gravels, gravel-sand mixtures, little or no fines.
		Gravels with fines	GM	Silty gravels, gravel-sand-silt mixtures.
			GC	Clayey gravels, gravel-sand-clay mixtures.
	SANDS More than half of coarse fraction is smaller than no. 4 sieve size.	Clean sands	SW	Well-graded sands, gravelly sands, little or no fines.
			SP	Poorly-graded sands, gravelly sands, little or no fines.
		Sands with fines	SM	Silty sands, sand-silt mixtures.
			SC	Clayey sands, sand-clay mixtures.
FINE GRAINED SOILS More than half of material is smaller than no. 200 sieve size.	SILTS AND CLAYS	Low liquid limit.	ML	Inorganic silts and very fine sands, rock flour, silty or clayey fine sands, or clayey silts, with slight plasticity.
			CL	Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays, lean clays.
			OL	Organic silts and organic silty clays of low plasticity.
		High liquid limit.	MH	Inorganic silts, micaceous or diatomaceous fine sandy or silty soils, elastic silts.
			CH	Inorganic clays of high plasticity, fat clays.
			OH	Organic clays of medium to high plasticity, organic silts.
Highly organic soils			Pt	Peat and other highly organic soils.



LEGEND

TH82-3A ● LOCATION AND NUMBER OF TEST HOLE

TT82-10AB ▬ LOCATION AND NUMBER OF TEST TRENCH

COMPOSITE GROUPING OF MATERIALS

Zone	Composite Classification (Weighted)
I	Clean, well, and poorly graded sands and gravels. (SP, SW, GP and GW)
II	Borderline sands and gravels (SP-SM, SW-SM, GP-GM, and GW-GP)
III	Sands and gravels with a significant proportion of fines (SM or GM)
IV	Fine silts (ML or MH)

* In accordance with Unified Soils Classification System

NOTES:

1.) Test trenches were excavated by backhoe during April, May, and June 1982.

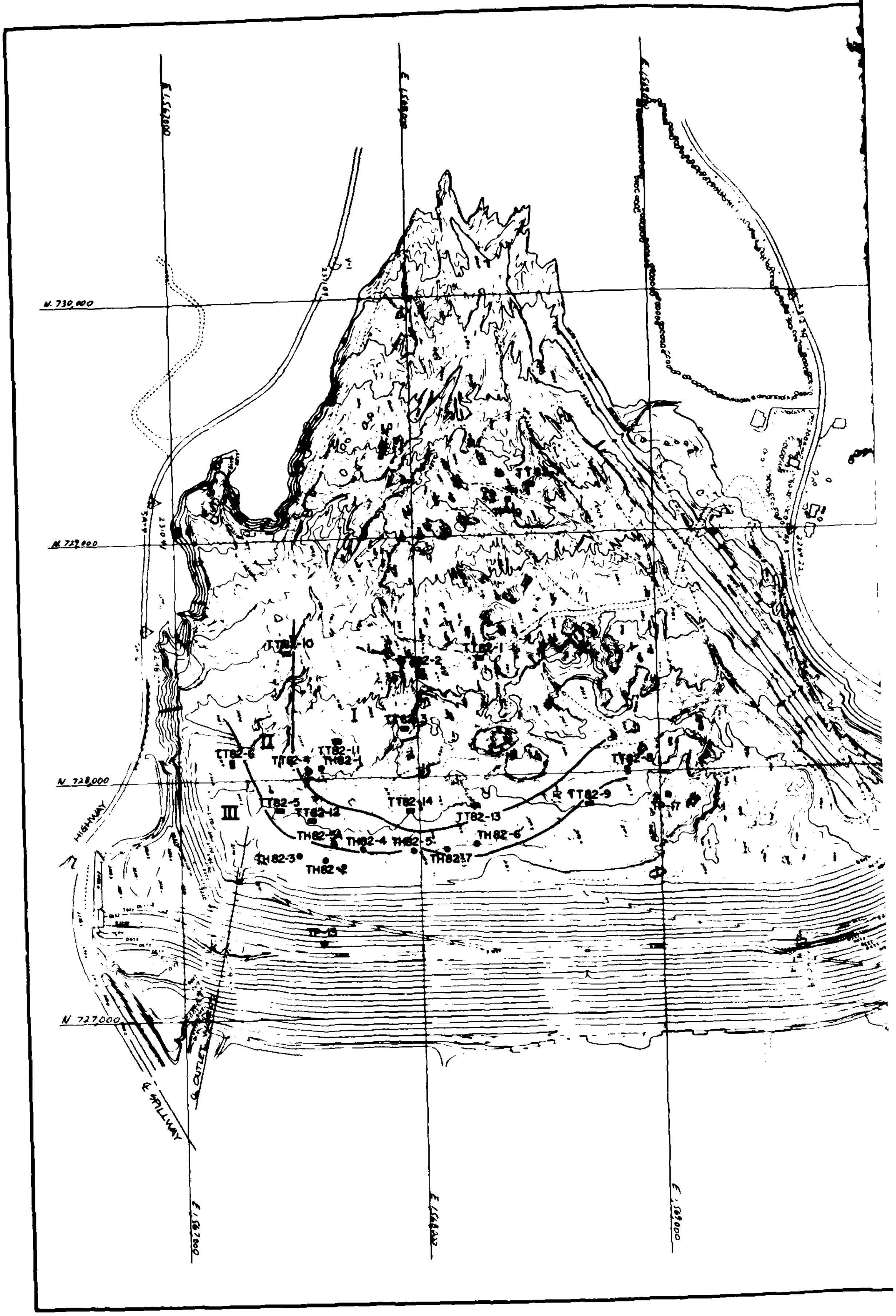
2.) Test holes were drilled by 24" diameter bucket auger during April, May, and June of 1982. Occasionally a 24" diameter flight auger was required to remove over sized material.

3.) Revert and water were used, in all drill holes below approximately 8' to prevent caving.

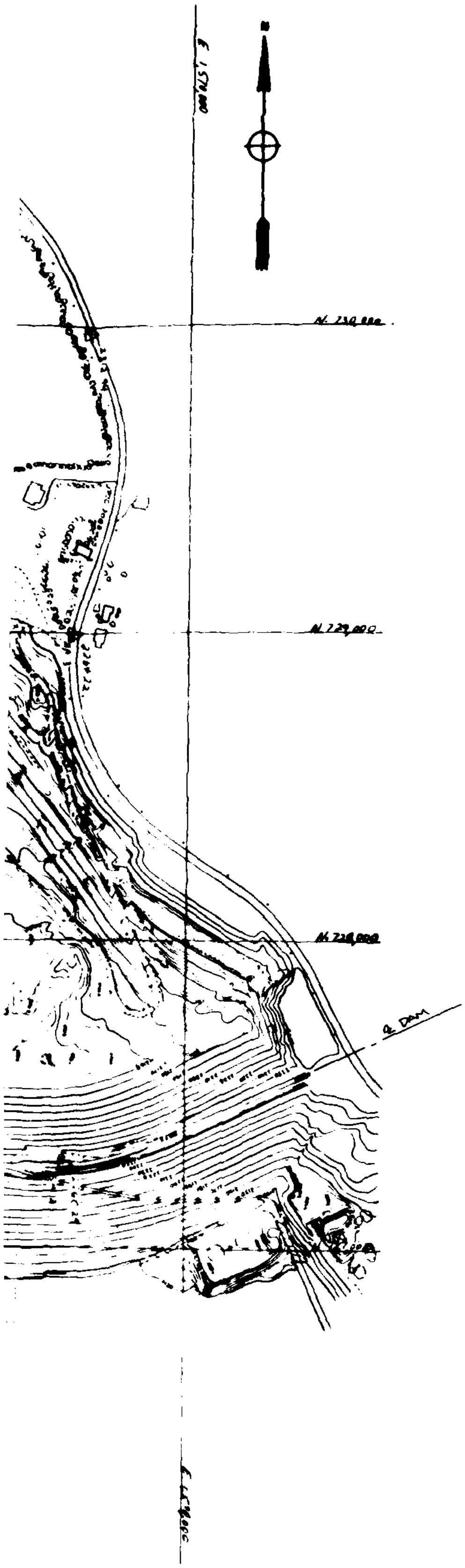
UPPER SANTA ANA RIVER
TWO-DIMENSIONAL GROUNDWATER AND SEDIMENT MODELING STUDIES

HANSEN DAM
PLAN OF EXPLORATION AND DISTRIBUTION OF DEPOSITED MATERIALS

FIGURE 4



N. 730,000
N. 729,000
N 728,000
N 727,000
TT82-10
TT82-1
TT82-2
TT82-3
TT82-6
TT82-4
TT82-11
TH82-1
TT82-8
TT82-5
TT82-12
TT82-14
TT82-13
TT82-9
TH82-4
TH82-5
TH82-6
TH82-7
TH82-3
TH82-2
I
II
III
HIGHWAY
SPILLWAY



NOTES

1. THB2-9 ● TEST HOLE DRILLED WITH BUCKET AUGER, JUNE 1982
2. TTB2-3 ▬ TEST TRENCH DUG WITH BACKHOE, JUNE 1982
3. TP 17 ■ TEST PIT EXCAVATED DURING ORIGINAL DAM FOUNDATION EXPLORATION, OCTOBER 1951

LEGEND

TP 17 ■ LOCATION AND NUMBER OF TEST PIT

THB2 2 ● LOCATION AND NUMBER OF TEST HOLE

TTB2 10 ▬ LOCATION AND NUMBER OF TEST TRENCH

COMPOSITE GROUPING OF MATERIALS

Zone	Composite Classification (Weighted)
I	Clean, well, and poorly graded sands and gravels (SP, SW, GP and GW*)
II	Borderline sands and gravels (SP-SM, SW-SM, GP-GM, and GW-GM*)
III	Sands and gravels with a significant proportion of fines (SM or GM*)
IV	Fine silts (ML or MH)

* In accordance with Unified Soils Classification System

UPPER SANTA ANA RIVER
TWO-DIMENSIONAL GROUNDWATER AND SEDIMENT MODELING STUDIES

SAN ANTONIO DAM
PLAN OF EXPLORATION AND
DISTRIBUTION OF DEPOSITED MATERIALS

FIGURE 5

TH 82-1F

PERCENT PASSING PER SIEVE SIZE

DEPTH	LOG	-3"	-1½"	-¾"	-⅜"	#-4	#-10	#-16	#-40	#-100	#-200	REMARKS
	SP	100	94	93	90	86	81	75	49	14	4	SAND
6.0'												
	SP SM				100	99	98	96	65	16	6	SAND-SILTY SAND
9.0'												
	ML							100	98	96	91	SILT
10.0'												
	SM				100	99	99	97	89	33	13	SILTY SAND water encountered at 2'.
	SM				100	99	99	98	95	72	27	
15.0'												
	SP SM					100	99	99	88	28	9	SAND-SILTY SAND
20.0'												
	SM					100	99	99	98	78	41	SILTY SAND
24.0'												
	GP GM	100	81	55	51	48	46	45	37	15	7	SANDY GRAVEL-SILTY SANDY GRAVEL 5% cobbles
27.0'												
	SP SM	100	93	77	63	54	49	44	34	15	7	GRAVELLY SAND-SILTY GRAVELLY SAND
	SP SM		100	99	96	93	89	87	71	22	7	SAND-SILTY SAND
32.0'												
	SP		100	92	86	78	70	61	38	10	4	GRAVELLY SAND
	SP		100	96	89	76	62	52	30	8	4	GRAVELLY SAND
38.0'												
	ML				100	99	98	97	94	90	85	SILT
45.0'												

TH 82-2A

PERCENT PASSING PER SIEVE SIZE

DEPTH	LOG	-3"	-1½"	-¾"	-⅜"	#-4	#-10	#-16	#-40	#-100	#-200	REMARKS
	SP SM					100	99	98	88	34	10	SAND-SILTY SAND
	SP SM		100	98	98	96	94	92	76	21	6	SAND-SILTY SAND some cobbles
	SP SM					100	99	99	93	36	10	
9.0'												
	ML						100	99	95	80	61	SILTY SAND
10.0'												
	SP SM	100	85	84	83	83	81	78	66	30	9	GRAVELLY SAND-SILTY GRAVELLY SAND
11.0'												

TH 82-3A

PERCENT PASSING PER SIEVE SIZE

DEPTH	LOG	-3"	-1½"	-¾"	-⅜"	#-4	#-10	#-16	#-40	#-100	#-200	REMARKS
	SP	100	97	94	90	86	79	71	37	8	3	SAND
	SP	100	98	94	91	87	83	78	50	9	3	
6.0'												
	SP SM		100	98	96	92	87	83	60	19	8	SAND-SILTY SAND brown
9.0'												
	SP		100	96	95	92	88	83	59	11	3	SAND
13.0'												
	ML					100	98	97	88	75	62	SANDY SILT, black.
14.0'												
	SP				100	98	97	95	71	12	3	SAND
15.0'												
	SP SM				100	99	98	96	82	28	8	SAND-SILTY SAND
18.0'												
	ML						100	99	97	88	65	SANDY SILT black
19.0'												
	SP SM	100	90	88	86	83	76	69	42	13	5	GRAVELLY SAND-SILTY GRAVELLY SAND 5% cobbles
22.0'												
	SP	100	84	77	72	66	61	56	34	9	3	GRAVELLY SAND 10% cobbles.
	SP	100	88	82	67	57	47	38	15	4	2	
	SP	100	75	70	64	58	50	42	16	4	2	
	SP	100	90	82	71	63	55	48	25	7	3	gray
36.0'												

T

PERCENT P

DEPTH	LOG	-3"	-1½"	-¾"
	SP SM	100	91	85
	SP SM	100	98	93
6.0'				
	SP	100	84	75
8.0'				
	ML			
9.0'				
	SP	100	96	92
12.0'				
	SM		100	99
15.0'				
	SP		100	99
	SP	100	96	89
	SP	100	93	89
	SP	91	81	70
27.0'				
	SM		100	98
	SM			100
34.5'				
	SM ML		100	96
36.0'				
	SP		100	92
40.0'				

T

PERCENT P

DEPTH	LOG	-3"	-1½"	-¾"
	ML			
6.0'				
6.5'	SP SM			
	SM			
12.0'				
	ML			
15.0'				
	SW SM		100	
22.0'				
	ML			
39.0'				
	SM	100	92	86
45.0'				

TH 82-4A

PERCENT PASSING PER SIEVE SIZE

DEPTH	LOG	3"	1½"	¾"	⅜"	#4	#10	#16	#40	#100	#200	REMARKS
	SP	100	91	85	81	78	75	68	37	12	5	GRAVELLY SAND-SILTY GRAVELLY SAND. brown
6.0'	SM	100	90	93	86	85	82	78	[illegible]	13	5	
9.0	SP	100	84	75	68	62	57	52	31	8	4	GRAVELLY SAND: brown
9.0'	ML							100	98	94	78	SILTY SAND: dark brown.
	SP	100	96	92	85	79	69	60	43	10	4	GRAVELLY SAND
	SM		100	99	96	91	87	84	71	40	19	SILTY SAND
			100	99	97	94	89	83	45	11	4	SAND
		100	96	89	83	77	72	63	29	8	3	GRAVELLY SAND: course sand, gray.
	SP	100	93	89	84	78	72	62	31	7	2	
		9	81	70	62	56	48	40	22	6	3	10% cobbles to 8 inches
			100	98	97	95	93	92	88	35	13	SILTY SAND, gray.
	SM			100	99	98	96	94	89	50	16	black.
	SM / SM		100	96	96	74	63	51	22	9	5	GRAVELLY SAND-SILTY GRAVELLY SAND. gray
	SP		100	92	90	68	59	52	28	12	6	GRAVELLY SAND

TH 82-6A

PERCENT PASSING PER SIEVE SIZE

DEPTH	LOG	3"	1½"	¾"	⅜"	#4	#10	#16	#40	#100	#200	REMARKS
3.0'	ML							100	99	86	56	SANDY SILT brown
	SM							100	99	81	47	SILTY SAND brown.
13.5'				100	99	97	96	93	85	64	37	gray
15.0'	SM / ML			100	96	88	88	79	49	15	7	SAND-SILTY SAND gray
24.0'	SP / SM				100	98	91	87	71	31	11	SAND-SILTY SAND gray
30.0'	SM				100	99	97	96	94	81	43	SILTY SAND. black
								100	99	94	64	SANDY SILT black, organic odor
	ML							100	98	97	95	SILT black, organic odor
47.0'						100	99	97	92	67	83	SANDY SILT black, organic odor
48.0'	SM	100	92	82	75	69	52	40	33	21	15	SILTY GRAVELLY SAND, some cobbles.

TH 82-5A

PERCENT PASSING PER SIEVE SIZE

DEPTH	LOG	3"	1½"	¾"	⅜"	#4	#10	#16	#40	#100	#200	REMARKS
	ML							100	98	81	59	SANDY SILT grayish-brown
	SP / SM						100	99	92	32	9	SAND-SILTY SAND light brown.
	SM							100	99	42	15	
							100	99	96	69	40	gray.
	ML								100	96	79	SANDY SILT gray
	SW / SM			100	99	96	92	83	49	14	6	SAND-SILTY SAND: gray, loose
						100	99	98	95	87	51	SANDY SILT. gray.
						100	99	93	77	66	56	
	ML					100	99	98	95	92	86	SILT. gray.
								100	99	89	65	SANDY SILT; gray.
	SM							100	98	79	38	SILTY SAND
		100	92	86	83	77	72	65	45	26	15	SILTY GRAVELLY SAND

NOTES

1. SEE FIGURE 4 FOR LOCATION OF TEST HOLES AND TEST TRENCHES.
2. SEE FIGURE 4 FOR LEGEND, NOTES, AND BASIS OF CLASSIFICATION.

UPPER SANTA ANA RIVER
TWO-DIMENSIONAL GROUNDWATER AND SEDIMENT MODELING STUDIES

HANSEN DAM

LOGS OF TEST HOLES AND TRENCHES

PARTIAL TABULATION

TH 82-7A

PERCENT PASSING PER SIEVE SIZE

DEPTH	LOG	-3"	-1½"	-¾"	-3/8"	-4	-10	-16	-40	-100	-200	REMARKS
	SM							100	99	71	25	SILTY SAND brown
							100	90	95	56	28	
9.0'	ML						100	95	88	78	69	SANDY SILT black,
						100	99	96	89	65	80	gray, roots found
								100	99	88	51	
								100	99	96	65	
21.0'	SM					100	99	98	95	57	23	SILTY SAND gray
24.0'	SP-SM			100	99	98	94	91	70	31	10	SAND-SILTY SAND gray, ground water encountered at 25.0'
25.0'	SW-SM		100	98	95	89	80	64	34	14	6	SAND-SILTY SAND
28.0'	SM				100	98	96	93	84	71	46	SILTY SAND black
								100	96	80	41	
			100	96	94	91	82	72	45	28	14	
43.0'	SW-SM		100	96	93	84	73	58	30	12	7	SAND-SILTY SAND
46.0'	SM				100	99	98	96	88	40	15	SILTY SAND
51.0'	SM	100	93	90	87	85	82	79	45	24	15	GRAVELLY SILTY SAND some gravel
54.0'	GP-GM	91	62	54	46	44	37	31	19	9	5	SANDY GRAVEL-SILTY SANDY GRAVEL some cobbles
55.0'												

TH 82-8A

PERCENT PASSING PER SIEVE SIZE

DEPTH	LOG	-3"	-1½"	-¾"	-3/8"	-4	-10	-16	-40	-100	-200	REMARKS
	SP-SM				100	99	98	96	75	20	8	SAND-SILTY SAND tan.
6.0'	SM						100	99	91	61	35	SILTY SAND tan.
12.0'	SP	100	97	91	86	80	68	58	34	9	4	GRAVELLY SAND
14.0'	SM				100	99	98	98	95	61	20	SILTY SAND
18.0'	ML				100	99	98	98	96	87	59	SANDY SILT.
							100	99	96	92	74	black.
27.0'	SW-SM		100	97	92	84	77	68	46	20	11	GRAVELLY SAND-SILTY GRAVELLY SAND
36.0'	SM		100	97	94	86	77	68	48	25	15	SILTY SAND
44.0'	SW-SM			100	99	89	65	53	28	13	8	SAND-SILTY SAND
47.0'	SP		100	99	90	75	33	26	16	7	4	GRAVELLY SAND, reddish-brown.
48.0'	ML					100	77	74	71	68	67	SANDY SILT
50.0'	SP-SM				100	54	42	35	18	8	3	GRAVELLY SAND-SILTY GRAVELLY SAND
50.5'												

TH 82-9A

PERCENT PASSING PER SIEVE SIZE

DEPTH	LOG	-3"	-1½"	-¾"	-⅜"	#-4	#-10	#-16	#-40	#-100	#-200	REMARKS
3.0'	SM							100	97	63	31	SILTY SAND
	ML							100	99	89	63	SANDY SILT
9.0'								100	98	93	73	
12.0'	SM				100	99	97	93	77	46	20	SILTY SAND, gray
15.0'	SP SM			100	99	96	90	83	58	27	11	SAND-SILTY SAND gray.
17.0'	ML							100	98	80	51	SANDY SILT gray.
21.0'	SM				100	98	90	94	81	57	31	SILTY SAND gray

TH 82-10A

PERCENT PASSING PER SIEVE SIZE

DEPTH	LOG	-3"	-1½"	-¾"	-⅜"	#-4	#-10	#-16	#-40	#-100	#-200	REMARKS
	SM							100	98	60	19	SILTY SAND
11.0'								100	98	76	48	
15.0'	ML							100	99	97	91	SILT

TH 82-11A

PERCENT PASSING PER SIEVE SIZE

DEPTH	LOG	-3"	-1½"	-¾"	-⅜"	#-4	#-10	#-16	#-40	#-100	#-200	REMARKS
3.0'	SM			100	99	98	97	96	87	46	21	SILTY SAND
6.0'	ML		100	97	96	95	93	92	88	76	51	SANDY SILT
10.0'	SM				100	99	98	96	95	89	48	SILTY SAND gray
12.0'	SP SM		100	99	98	98	93	89	74	30	10	SAND-SILTY SAND gray
18.0'	SP	100	93	92	91	88	85	80	46	8	2	SAND gray, ground water encountered at 18'

TH 82-12A

PERCENT PASSING PER SIEVE SIZE

DEPTH	LOG	-3"	-1½"	-¾"	-⅜"	#-4	#-10	#-16	#-40	#-100	#-200	REMARKS
9.0'	SM						100	98	96	62	30	SILTY SAND
10.0'	ML					[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	SANDY SILT black.
	SM					100	99	98	96	83	40	SILTY SAND medium, gray.
15.0'				100	99	98	96	94	68	34	16	

NOTES

1 SEE FIGURE 4 FOR LOCATION OF TEST HOLES AND TEST TRENCHES.

2 SEE FIGURE 4 FOR LEGEND. NOTES. AND BASIS OF CLASSIFICATION.

UPPER SANTA ANA RIVER
TWO-DIMENSIONAL GROUNDWATER AND SEDIMENT MODELING STUDIES

HANSEN DAM

LOGS OF TEST HOLES AND TRENCHES

PARTIAL TABULATION

FIGURE 7

TT 82-1AB

DEPTH	LOG	-3"	-1½"	-¾"	-3/8"	-#4	-#10	-#16	-#40	-#100	-#200	REMARKS
	SP	100	90	83	72	62	55	46	27	7	2	GRAVELLY SAND, 5% cobbles.
6.0'						100	99	96	72	18	4	SAND
8.5'	SP SM	100	89	84	83	81	80	77	50	18	8	GRAVELLY SAND-SILTY GRAVELLY SAND, 10% cobbles, ground water encountered @ 8.5'

PERCENT PASSING per SIEVE SIZE

TT 82-2AB

DEPTH	LOG	-3"	-1½"	-¾"	-3/8"	-#4	-#10	-#16	-#40	-#100	-#200	REMARKS
	SP	90	82	76	71	66	60	50	18	3	1	GRAVELLY SAND, 5% cobbles, ground water encountered @ 6'
6.0'		100	94	90	87	84	80	76	61	7	2	

PERCENT PASSING per SIEVE SIZE

TT 82-3AB

DEPTH	LOG	-3"	-1½"	-¾"	-3/8"	-#4	-#10	-#16	-#40	-#100	-#200	REMARKS
3.0'	SP			100	99	94	89	78	30	5	2	SAND
6.0'	SM					100	99	98	94	56	17	SILTY SAND, ground water encountered @ 6'

PERCENT PASSING per SIEVE SIZE

TT 82-4AB

DEPTH	LOG	-3"	-1½"	-¾"	-3/8"	-#4	-#10	-#16	-#40	-#100	-#200	REMARKS
		100	90	76	64	54	46	39	13	1	0	GRAVELLY SAND, 5% cobbles to 3'
	SP	93	75	67	61	54	49	42	17	4	2	20% Cobbles below 3' Ground water @ 9'
9.0'		81	81	78	77	75	73	70	58	10	2	

PERCENT PASSING per SIEVE SIZE

TT 82-5AB

DEPTH	LOG	-3"	-1½"	-¾"	-3/8"	-#4	-#10	-#16	-#40	-#100	-#200	REMARKS
1.0'	SP SM							100	97	45	8	SAND-SILTY SAND
4.0'	SP	–	–	–	–	–	–	–	–	–	–	SAND, 5% cobbles, 5% gravels Visually logged only. Ground water @ 4'

PERCENT PASSING per SIEVE SIZE

TT 82-6AB

DEPTH	LOG	-3"	-1½"	-¾"	-3/8"	-#4	-#10	-#16	-#40	-#100	-#200	REMARKS
			100	99	98	97	96	92	48	5	1	SAND
5.0'	SP	100	86	81	75	69	61	50	17	1	0	GRAVELLY SAND, 10% gravel Ground water encountered @ 5'

PERCENT PASSING per SIEVE SIZE

DEPTH	LOG	-3"	-1½"
1.5'	SP		
2.0	SM		
	ML		
14.0			

DEPTH	LOG	-3"	-1½"
3.0'	SP		
	SM		
12.0			
12.5'	SM SM		100

DEPTH	LOG	-3"	-1½"
2.0'	SP		100
2.5'	SM		
4.5'	SP		
6.0'	ML		
6.5'	SP		100
7.0'	SM		
10.0'	SP		
14.0'	SM		100
18.0'	ML		

DEPTH	LOG	-3"	-1½"
2.0'	ML		
4.0'	SP		
4.5'	ML		
5.5'	SM		
7.0'	SP SM		
8.0'	SP	100	88
10.0'	SP		
18.0'	SM		

TT 82-7AB

PERCENT PASSING per SIEVE SIZE

DEPTH	LOG	-3"	-1½"	-¾"	-3/8"	-#4	-#10	-#16	-#40	-#100	-#200	REMARKS
1.6'	SP			100	98	96	91	84	62	6	1	SAND
3.0'	SM							100	98	58	20	SILTY SAND, ground water encountered @ 3'
	ML								100	97	77	SANDY SILT
14.0	ML								100	98	98	SILT

TT 82-8AB

PERCENT PASSING per SIEVE SIZE

DEPTH	LOG	-3"	-1½"	-¾"	-3/8"	-#4	-#10	-#16	-#40	-#100	-#200	REMARKS
3.0	SP				100	98	97	94	79	17	2	SAND
	SM							100	97	60	27	SILTY SAND
12.0	SM					100	98	98	96	71	32	black root odor, ground water encountered @ 12'
12.5'	SP-SM		100	98	97	95	90	82	62	15	8	SAND-SILTY SAND

TT 82-9AB

PERCENT PASSING per SIEVE SIZE

DEPTH	LOG	-3"	-1½"	-¾"	-3/8"	-#4	-#10	-#16	-#40	-#100	-#200	REMARKS
2.0'	SP		100	98	97	94	90	86	56	10	2	SAND
2.5'	SM					100	98	97	89	79	20	SILTY SAND
4.5'	SP			100	97	95	92	87	47	3	0	SAND
6.0'	ML						100	98	90	62	53	SANDY SILT
6.5'	SP		100	98	98	98	96	93	71	15	3	SAND
7.0'	SM						100	98	98	87	46	SILTY SAND
10.0'	SP					100	98	96	78	12	2	SAND
14.0'	SM		100	99	98	98	98	96	87	54	30	SILTY SAND
	ML							100	98	97	94	SILT
18.0'	ML							100	97	90	88	

TT 82-10AB

PERCENT PASSING per SIEVE SIZE

DEPTH	LOG	-3"	-1½"	-¾"	-3/8"	-#4	-#10	-#16	-#40	-#100	-#200	REMARKS
2.0'	ML						100	98	94	87	80	SANDY SILT
4.0'	SP			100	99	98	94	88	55	7	1	SAND
4.5'	ML					100	98	95	85	77	56	SANDY SILT
5.5'	SM								100	83	29	SILTY SAND
7.0'	SP-SM					100	99	98	82	41	8	SAND-SILTY SAND
8.0'	GP	100	83	68	56	50	46	43	30	6	1	SANDY GRAVEL
10.0'	SP						100	90	60	24	4	SAND
	SM						100	99	97	77	30	SILTY SAND
	SM					100	98	98	92	80	20	
18.0'	SM					100	98	95	78	69	48	black
									100	80	25	

TT 82-12AB

PERCENT PASSING per SIEVE SIZE

DEPTH	LOG	-3"	-1½"	-¾"	-3/8"	-#4	-#10	-#16	-#40	-#100	-#200	REMARKS
2.0'	SP	—	—	—	—	—	—	—	—	—	—	SAND, coarse with 10% gravels
2.6'	SM								100	74	25	SILTY SAND
4.5'	ML								100	98	61	SANDY SILT
5.0'	SM								100	88	41	SILTY SAND
5.5'	ML								100	99	94	SILT
6.5'	SM								100	85	31	SILTY SAND
7.5'	ML							100	99	98	95	SILT
10.0'	SM								100	54	16	SILTY SAND
15.0'	ML						100	98	96	94	90	SILT, dark gray
17.0'	SP-SM			100	98	96	92	89	79	34	9	SAND-SILTY SAND, light gray
18.0'	ML							100	98	93	87	SILT

TT 82-13AB

PERCENT PASSING per SIEVE SIZE

DEPTH	LOG	-3"	-1½"	-¾"	-3/8"	-#4	-#10	-#16	-#40	-#100	-#200	REMARKS
6.0'	SM							100	98	56	20	SILTY SAND
	SP-SM							100	94	26	10	SAND-SILTY SAND
10.0'	SP-SM								100	56	12	
11.0'	SM							100	97	88	20	SILTY SAND
13.0'	SP	100	86	85	82	80	76	72	40	8	1	GRAVELLY SAND
14.0'	ML								100	90	51	SANDY SILT

TT 82-14AB

PERCENT PASSING per SIEVE SIZE

DEPTH	LOG	-3"	-1½"	-¾"	-3/8"	-#4	-#10	-#16	-#40	-#100	-#200	REMARKS
6.0'	SP					100	99	98	94	29	4	SAND
7.0'	SM							100	98	57	15	SILTY SAND
10.0'	SP-SM			100	99	96	80	68	40	14	5	SAND-SILTY SAND
14.0'	SP		100	96	91	83	67	57	33	8	2	GRAVELLY SAND, stop trench due to caving

NOTES:

1. SEE FIGURE 4 FOR LOCATION OF TEST HOLES AND TEST TRENCHES
2. SEE FIGURE 4 FOR LEGEND, NOTES, AND BASIS OF CLASSIFICATION

UPPER SANTA ANA RIVER
TWO-DIMENSIONAL GROUNDWATER AND SEDIMENT MODELING STUDIES

HANSEN DAM
LOGS OF TEST HOLES AND TRENCHES
PARTIAL TABULATION

FIGURE

TH82-1

DEPTH	LOG	-3"	-1½"	-¾"	-3/8"	-#4	-#10	-#16	-#40	-#100	-#200	REMARKS
		PERCENT PASSING per SIEVE SIZE										
6.0'	GP	100	90	72	60	40	38	32	16	5	3	SANDY GRAVEL, 5% cobbles, 3% boulders, hole stopped due to caving

TH82-2

DEPTH	LOG	-3"	-1½"	-¾"	-3/8"	-#4	-#10	-#16	-#40	-#100	-#200	REMARKS
		PERCENT PASSING per SIEVE SIZE										
	SM	100	95	91	85	78	75	72	63	37	10	SILTY GRAVELLY SAND Ground water encountered @ 4.5'
			100	98	94	91	88	85	78	50	24	SILTY SAND, tan
								100	90	85	43	Black
18.0'						100	99	98	94	80	33	Organic
25.0'	ML								100	97	94	SILT, black
27.0'	SM		100	95	88	82	78	74	63	48	42	GRAVELLY SILTY SAND, black
30.0'	SW-SM	100	97	95	90	84	73	67	45	16	10	GRAVELLY SAND-SILTY GRAVELLY SAND, black
31.0'	GM	100	97	74	63	55	44	38	27	20	17	SILTY SANDY GRAVEL, black

TH82-3

DEPTH	LOG	-3"	-1½"	-¾"	-3/8"	-#4	-#10	-#16	-#40	-#100	-#200	REMARKS
		PERCENT PASSING per SIEVE SIZE										
6.0'	SM		100	93	86	80	72	67	54	33	21	GRAVELLY SILTY SAND
15.0'	SP-SM	100	96	94	87	80	71	67	55	15	5	GRAVELLY SAND-SILTY GRAVELLY SAND
21.0'	ML								100	97	91	SILT, black
23.0'	SM	100	96	87	79	72	66	60	47	31	23	SILTY GRAVELLY SAND, brown, 5% cobbles

TH82-3A

DEPTH	LOG	-3"	-1½"	-¾"	-3/8"	-#4	-#10	-#16	-#40	-#100	-#200	REMARKS
		PERCENT PASSING per SIEVE SIZE										
3.0'		—	—	—	—	—	—	—	—	—	—	GRAVELLY SAND-SILTY GRAVELLY SAND, brown, 5% cobbles

TH82-4

DEPTH	LOG	-3"	-1½"	-¾"	-3/8"	-#4	-#10	-#16	-#40	-#100	-#200	REMARKS
		PERCENT PASSING per SIEVE SIZE										
	SP-SM	100	88	78	66	54	46	41	26	8	5	GRAVELLY SAND-SILTY GRAVELLY SAND
5.0'		100	88	80	72	64	57	51	30	13	6	Some cobbles

TH82-5

PERCENT PASSING per SIEVE SIZE

DEPTH	LOG	-3"	-1½"	-¾"	-3/8"	-#4	-#10	-#16	-#40	-#100	-#200	REMARKS
	SP SM	100	80	75	72	63	56	51	30	12	7	GRAVELLY SAND-SILTY GRAVELLY SAND, brown, some cobbles
	SM	100	95	91	86	82	78	75	50	30	24	GRAVELLY SILTY SAND, black

TH82-6

PERCENT PASSING per SIEVE SIZE

DEPTH	LOG	-3"	-1½"	-¾"	-3/8"	-#4	-#10	-#16	-#40	-#100	-#200	REMARKS
	SM	100	95	89	85	81	78	76	69	41	19	GRAVELLY SILTY SAND, brown
	SP SM		100	94	86	75	68	60	35	15	7	GRAVELLY SAND-SILTY GRAVELLY SAND, gray

TH82-7

PERCENT PASSING per SIEVE SIZE

DEPTH	LOG	-3"	-1½"	-¾"	-3/8"	-#4	-#10	-#16	-#40	-#100	-#200	REMARKS
	SP SM	100	80	75	66	57	50	43	28	15	10	GRAVELLY SAND-SILTY GRAVELLY SAND

TT82-1

PERCENT PASSING per SIEVE SIZE

DEPTH	LOG	-3"	-1½"	-¾"	-3/8"	-#4	-#10	-#16	-#40	-#100	-#200	REMARKS
		–	–	–	–	–	–	–	–	–	–	GRAVELLY SAND, very coarse sands, 30% cobbles, with some boulders
		–	–	–	–	–	–	–	–	–	–	SANDY GRAVEL, 40% cobbles, 15% boulders, very coarse sand

Below 12', material much coarser stopped @ 15' due to large boulders

TT82-2

PERCENT PASSING PER SIEVE SIZE

DEPTH	LOG	-3"	-1½"	-¾"	-3/8"	-#4	-#10	-#16	-#40	-#100	-#200	REMARKS
	SP SM	100	80	79	76	71	66	64	30	13	6	GRAVELLY SAND-SILTY GRAVELLY SAND
2.2	GP	100	70	53	41	32	28	21	9	3	1	SANDY GRAVEL, 30% cobbles, 5% boulders
	GP	100	80	62	46	38	31	25	10	3	1	10% Boulders @ 4'
9.2												

TT82-3

PERCENT PASSING per SIEVE SIZE

DEPTH	LOG	-3"	-1½"	-¾"	-3/8"	-#4	-#10	-#16	-#40	-#100	-#200	REMARKS
	SP SM		100	97	90	90	86	78	60	17	6	SAND-SILTY SAND; 10% Cobbles @ 3'
6.0	GP	100	65	62	50	27	16	17	10	3	1	SANDY GRAVEL
11.0	SP	100	86	78	69	66	49	42	20	8	3	GRAVELLY SAND, 6% cobbles, 30% boulders
15.0												

TT82-4

PERCENT PASSING per SIEVE SIZE

DEPTH	LOG	-3"	-1½"	-¾"	-3/8"	-#4	-#10	-#16	-#40	-#100	-#200	REMARKS
		–	–	–	–	–	–	–	–	–	–	GRAVELLY SAND, 20% cobbles with some boulders
3.0'		–	–	–	–	–	–	–	–	–	–	Same, but 30% cobbles
9.0'		–	–	–	–	–	–	–	–	–	–	Same, but 5% boulders to 20 inches
11.0'	SP	–	–	–	–	100	99	99	66	19	6	SAND, clean, fine
15.0'												

TT82-5

PERCENT PASSING per SIEVE SIZE

DEPTH	LOG	-3"	-1½"	-¾"	-3/8"	-#4	-#10	-#16	-#40	-#100	-#200	REMARKS
0.5'	SM							100	97	51	18	SILTY SAND
	ML								100	98	88	SILT, gray
1.5'								100	99	93	51	SANDY SILT, reddish brown
	SP		100	99	97	95	87	80	42	7	3	SAND, 30% cobbles; No cobbles from 3' - 3.5'
	SP		100	98	98	98	97	95	73	13	3	25% Cobbles
13.0'	SP SM							100	98	56	10	SAND-SILTY SAND, organic matter
15.0'	SM				100	98	98	98	98	82	15	SILTY SAND, gray, organic matter
16.0'												

TT82-6

PERCENT PASSING per SIEVE SIZE

DEPTH	LOG	-3"	-1½"	-¾"	-3/8"	-#4	-#10	-#16	-#40	-#100	-#200	REMARKS
	ML							100	99	93	65	SANDY SILT, gray
1.0'	SW SM							100	99	93	65	SAND-SILTY SAND, dark brown, organic matter
5.5'												@ 4.5' Asphalt slab L≥60' W≥25' encountered

TT82-7

PERCENT PASSING per SIEVE SIZE

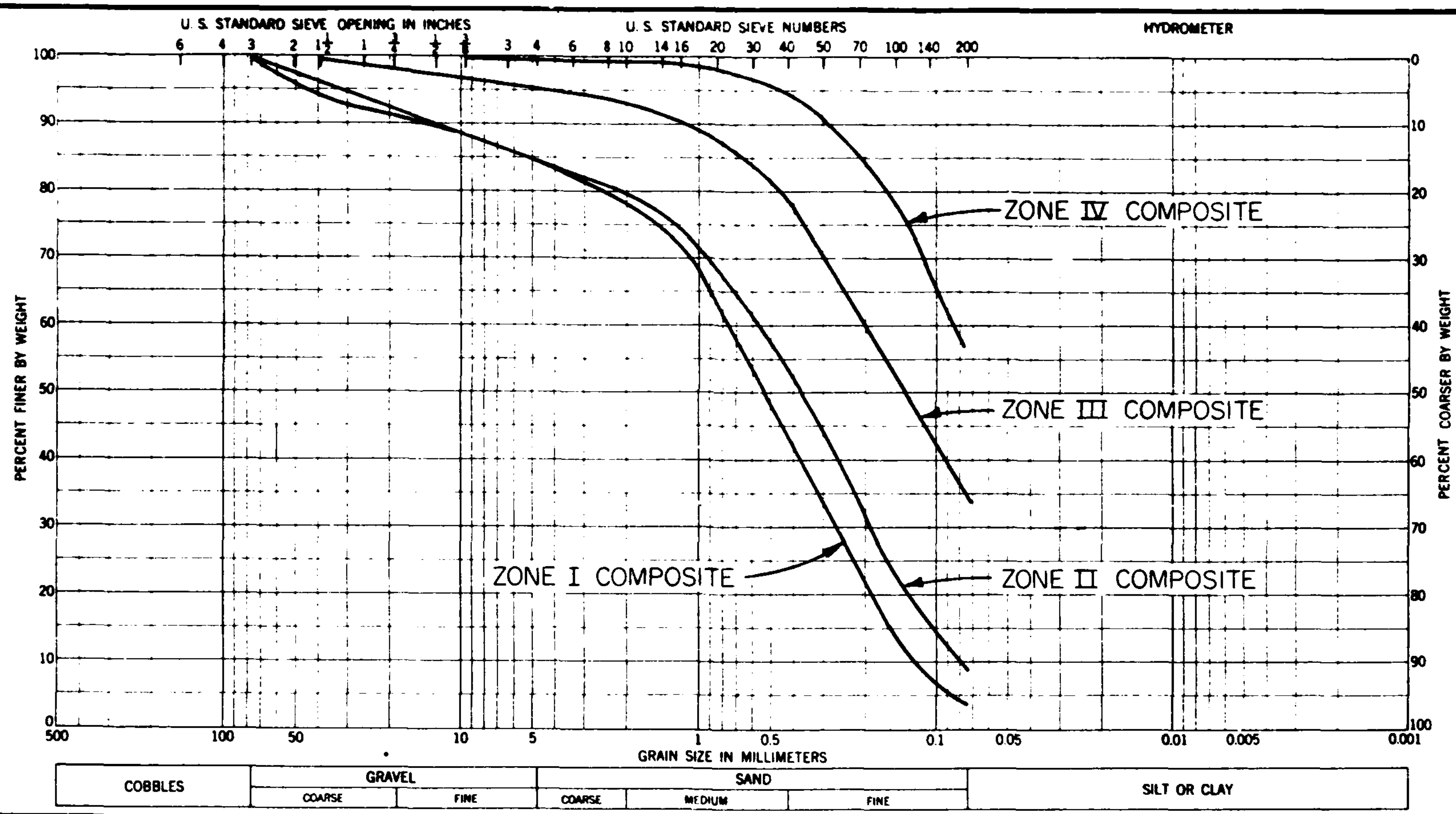
DEPTH	LOG	-3"	-1½"	-¾"	-3/8"	-#4	-#10	-#16	-#40	-#100	-#200	REMARKS
		–	–	–	–	–	–	–	–	–	–	GRAVELLY SAND, with 30% cobbles, 20% gravels
6.0'												

NOTES:
1. SEE FIGURE 5 FOR LOCATION OF TEST HOLES AND TEST TRENCHES.
2. SEE FIGURE 4 FOR LEGEND, NOTES, AND BASIS OF CLASSIFICATION.

UPPER SANTA ANA RIVER
TWO-DIMENSIONAL GROUNDWATER AND SEDIMENT MODELING STUDIES

SAN ANTONIO DAM
LOGS OF TEST HOLES AND TRENCHES
PARTIAL TABULATION

FIGURE 9



Sample No.	Elev or Depth	Classification	Nat w %	LL	PL	PI

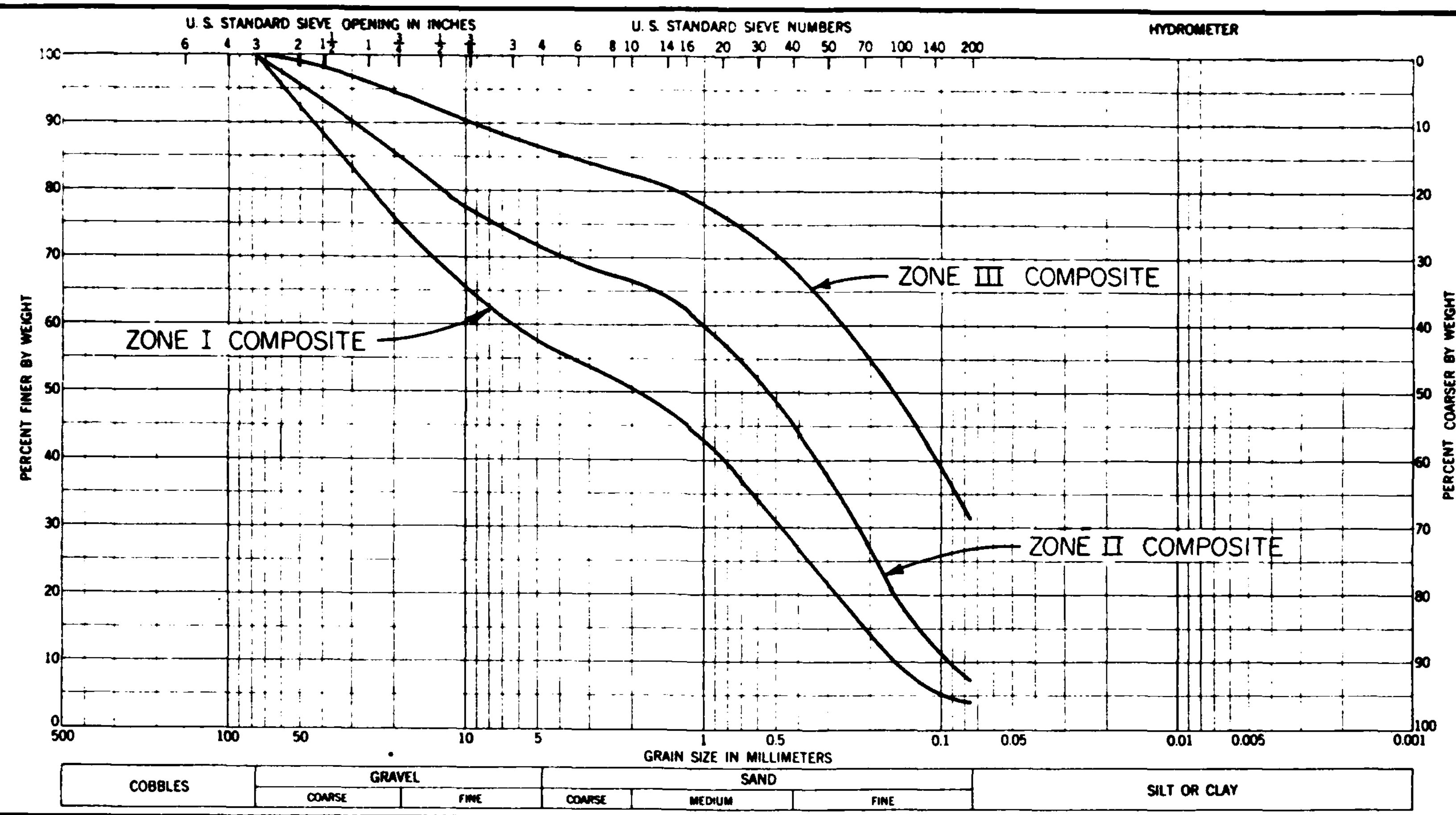
Project: HANSEN DAM
DEPOSITED MATERIALS
ZONES I, II, III & IV
COMPOSITE GRADATIONS

Date

GRADATION CURVES

ENG FORM 1 MAY 63 2087

FIGURE 10



Sample No.	Elev or Depth	Classification	Nat w %	LL	PL	PI

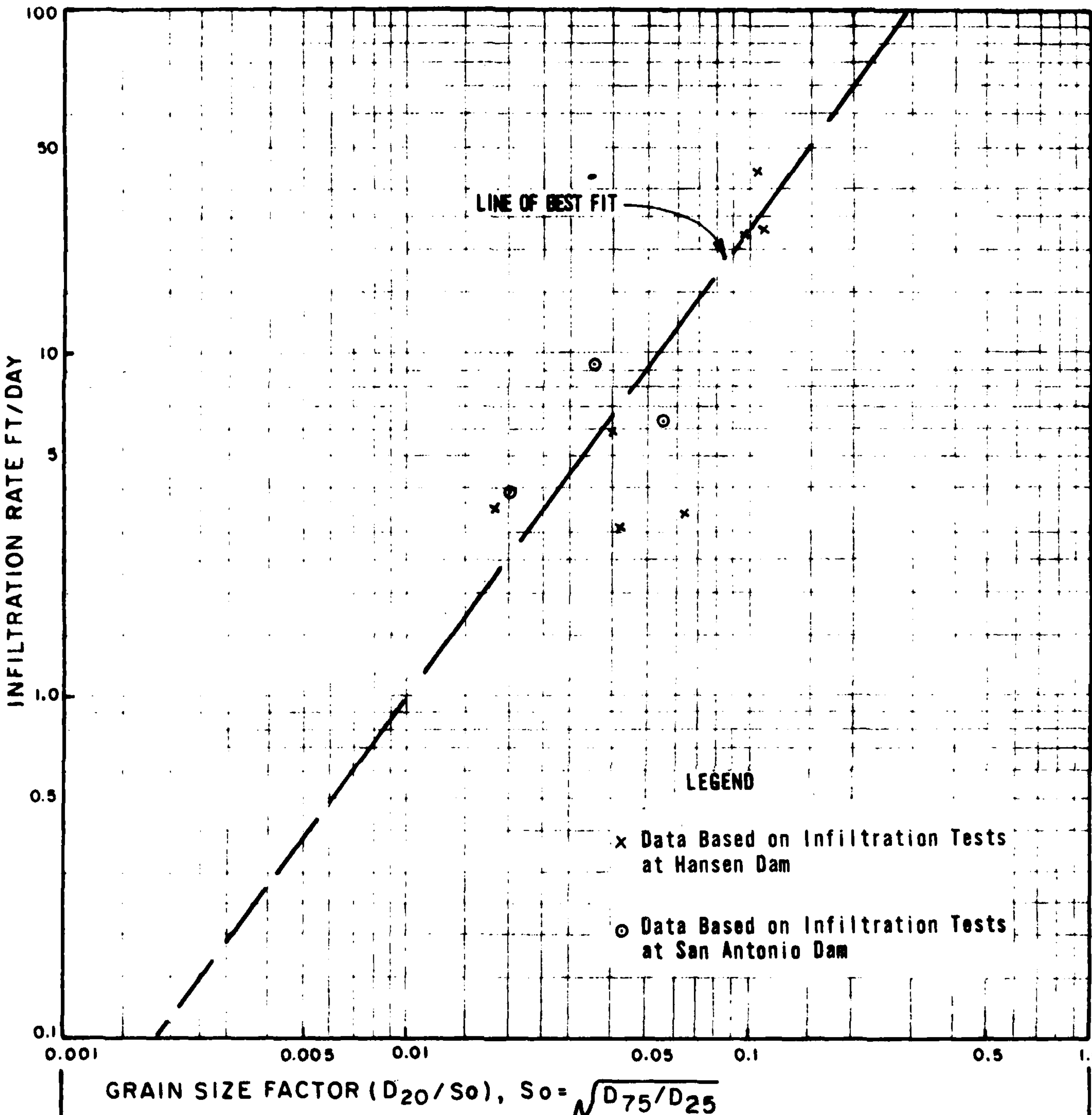
Project SAN ANTONIO DAM
DEPOSITED MATERIALS
ZONES I, II & III
COMPOSITE GRADATIONS

Date

GRADATION CURVES

ENG FORM 1 MAY 63 2087

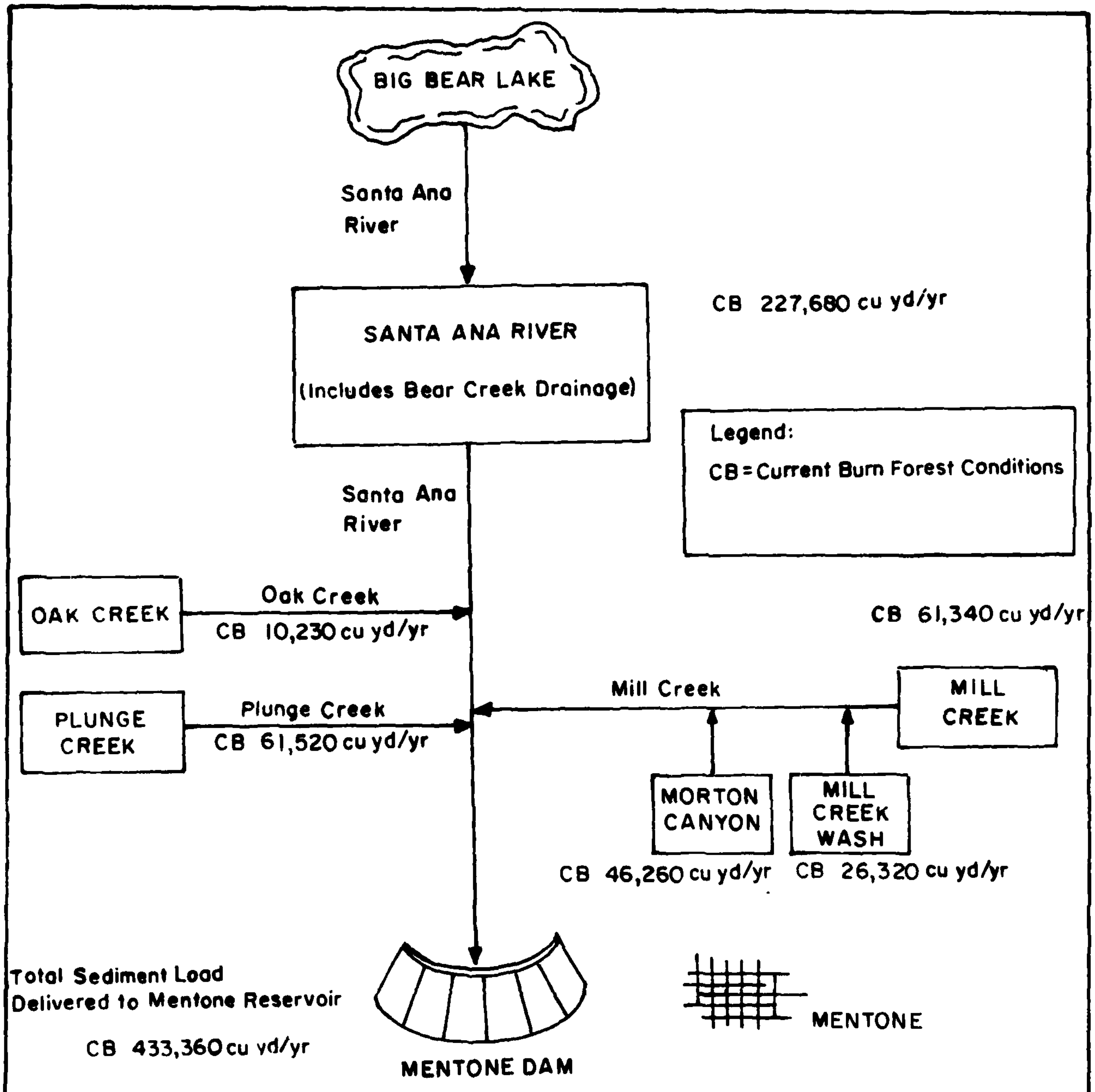
FIGURE 11



UPPER SANTA ANA RIVER
TWO-DIMENSIONAL GROUNDWATER AND SEDIMENT MODELING STUDIES

CORRELATION OF INFILTRATION RATE WITH GRAIN SIZE FACTOR SEDIMENT DEPOSITS IN HANSEN AND SAN ANTONIO RESERVOIRS

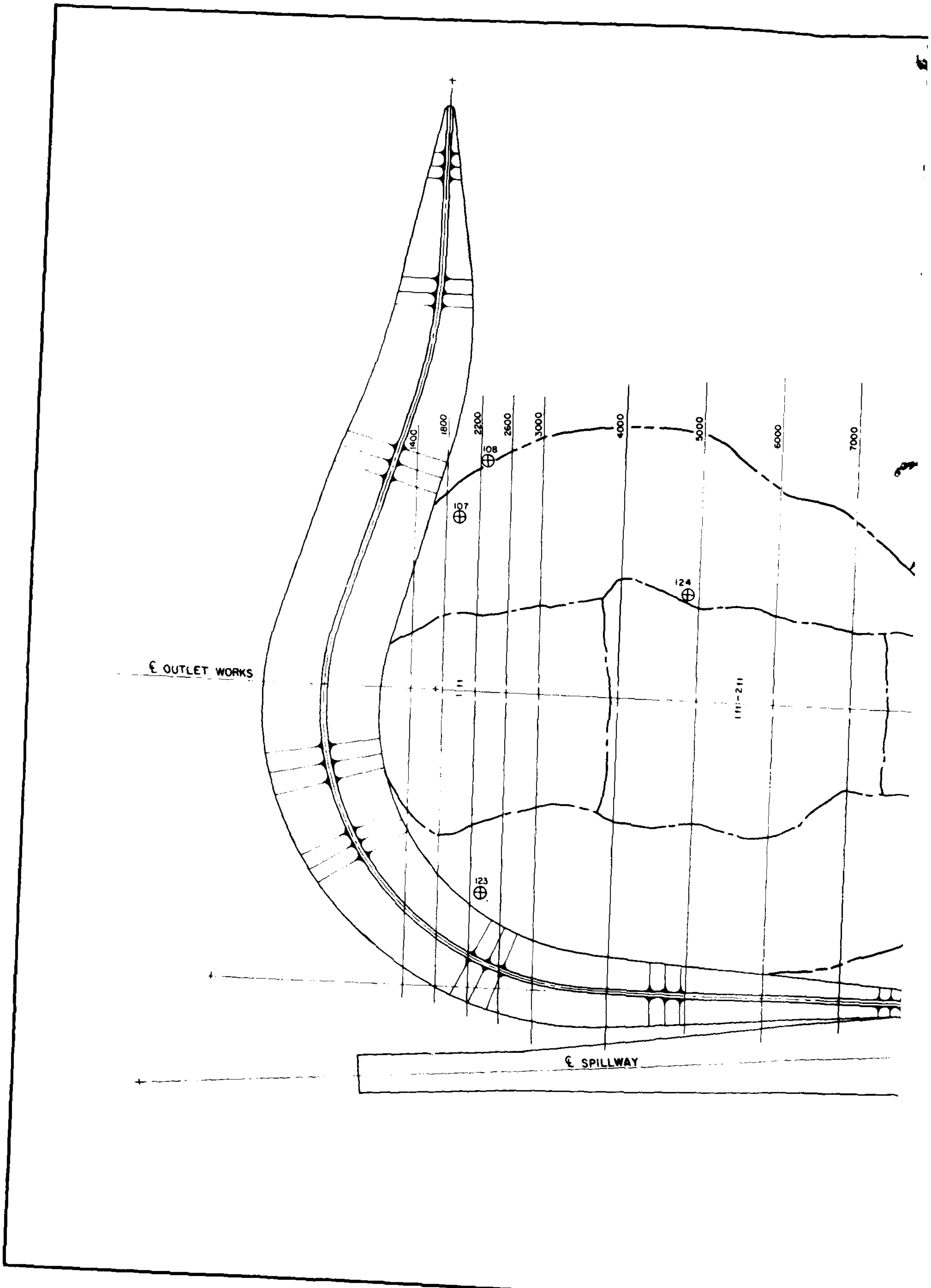
FIGURE 12



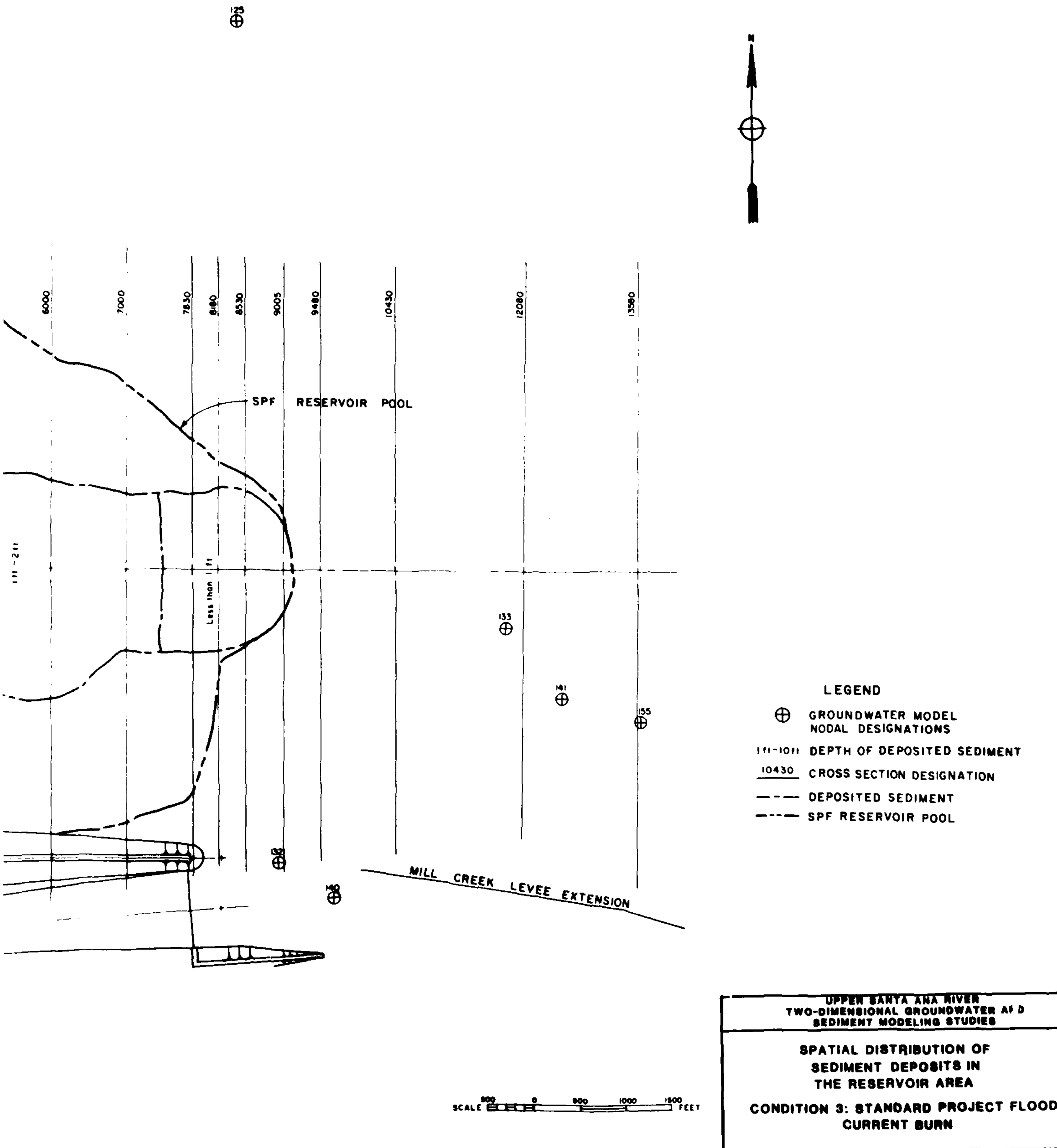
UPPER SANTA ANA RIVER
TWO-DIMENSIONAL GROUNDWATER AND SEDIMENT STUDIES

RUNOFF AND SEDIMENT CONTRIBUTING WATERSHEDS FOR THE SANTA ANA RIVER AT MENTONE, CALIFORNIA WITH ESTIMATED AVERAGE ANNUAL SEDIMENT PRODUCTION RATES FOR CURRENT BURN-FOREST CONDITION

FIGURE 13



℄ OUTLET WORKS
℄ SPILLWAY
1400
1800
2200
2600
3000
4000
5000
6000
7000
108
107
124
123

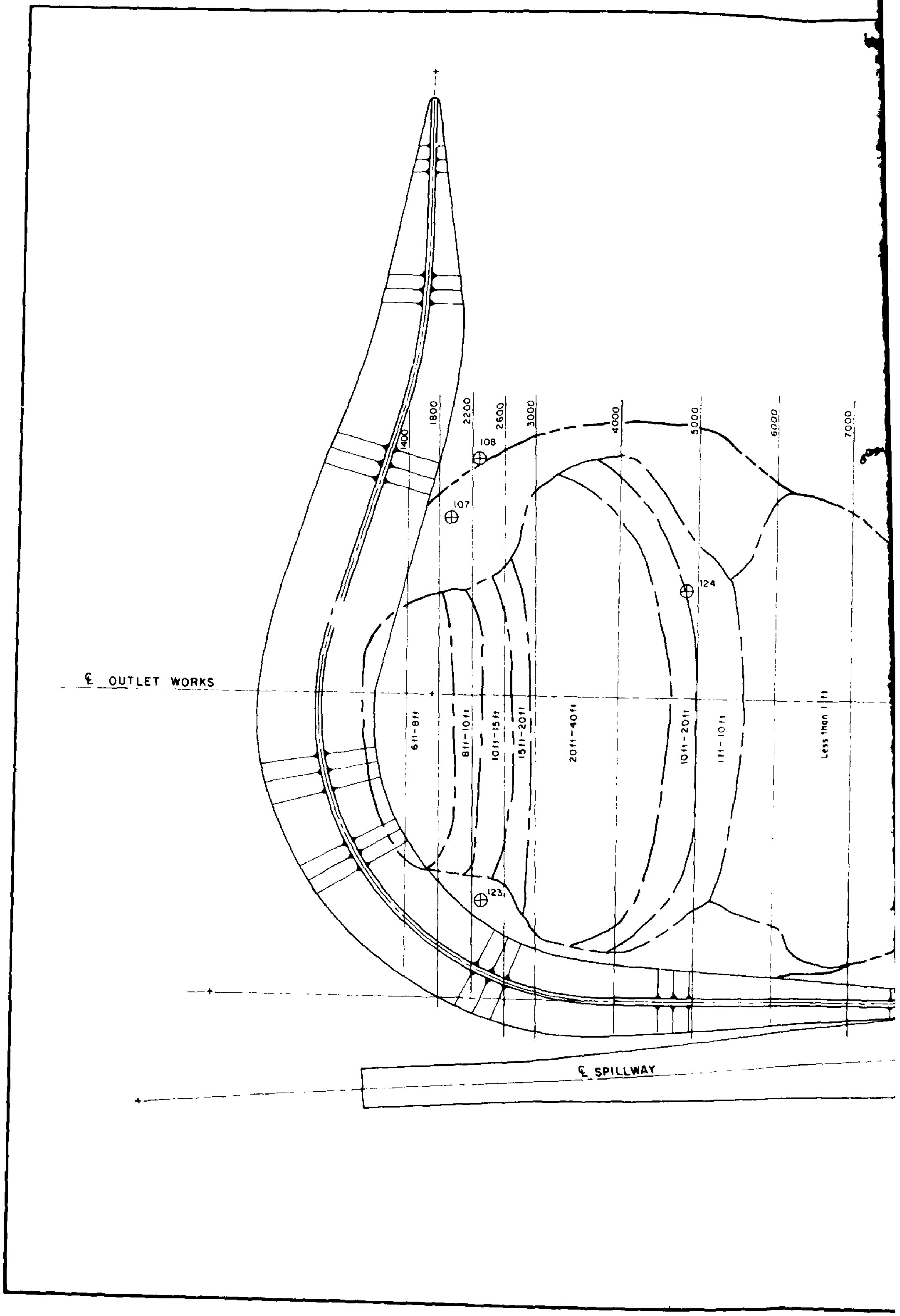


UPPER SANTA ANA RIVER
TWO-DIMENSIONAL GROUNDWATER AND
SEDIMENT MODELING STUDIES

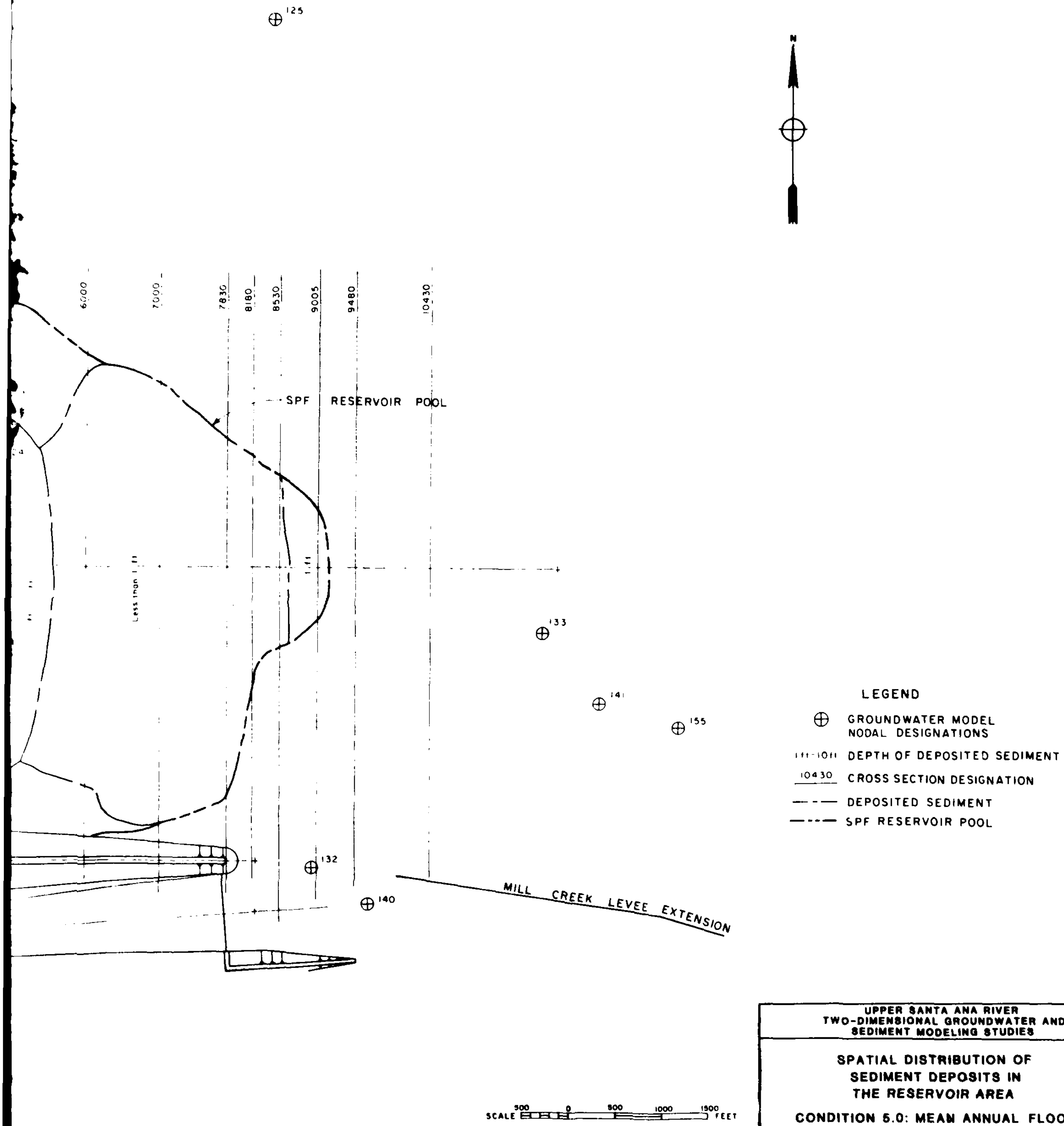
SPATIAL DISTRIBUTION OF
SEDIMENT DEPOSITS IN
THE RESERVOIR AREA

CONDITION 3: STANDARD PROJECT FLOOD,
CURRENT BURN

FIGURE 14



1400
1800
2200
2600
3000
4000
5000
6000
7000
108
107
124
123
℄ OUTLET WORKS
6ft-8ft
8ft-10ft
10ft-15ft
15ft-20ft
20ft-40ft
10ft-20ft
1ft-10ft
Less than 1ft
℄ SPILLWAY

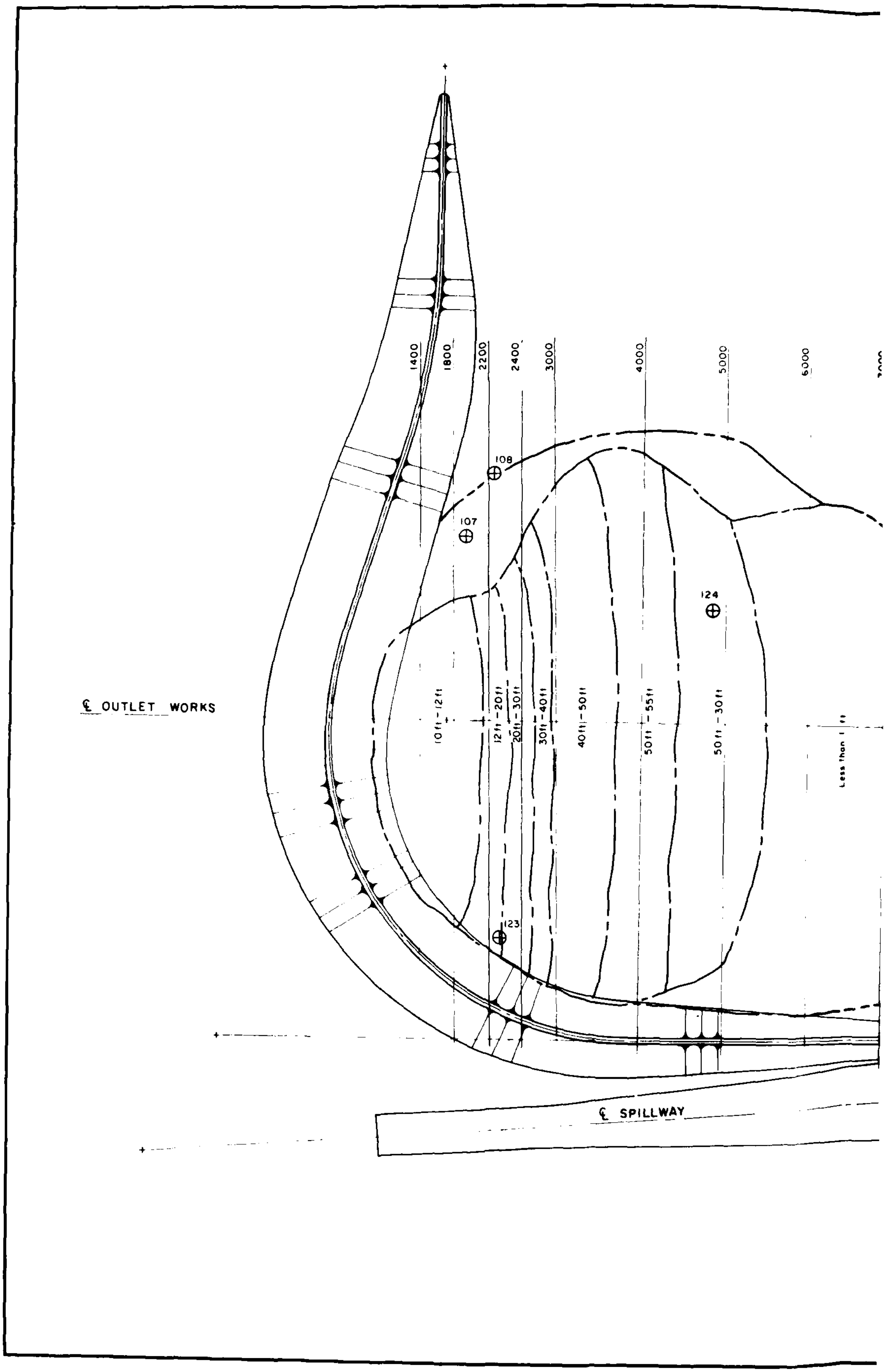


UPPER SANTA ANA RIVER
TWO-DIMENSIONAL GROUNDWATER AND
SEDIMENT MODELING STUDIES

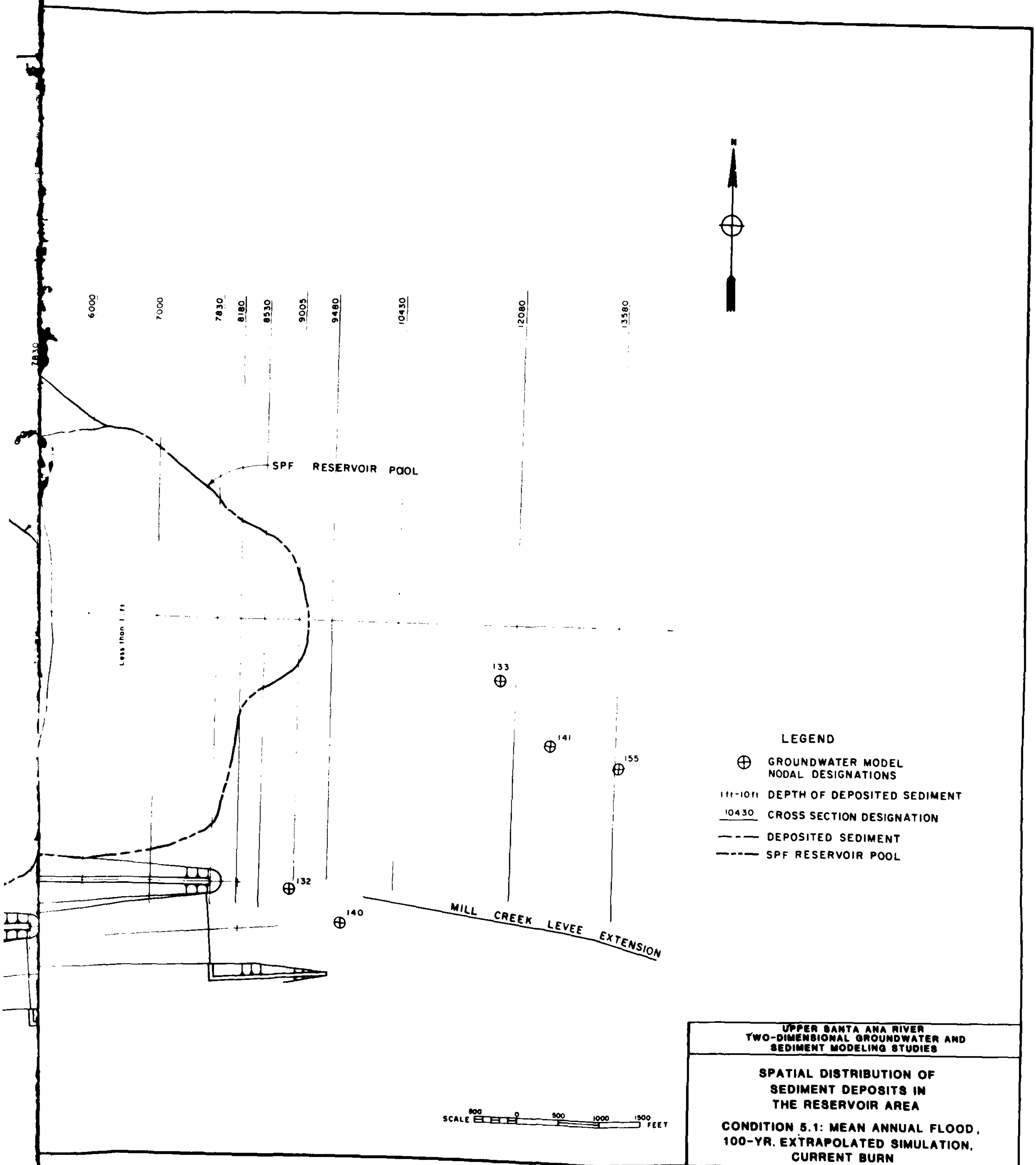
SPATIAL DISTRIBUTION OF
SEDIMENT DEPOSITS IN
THE RESERVOIR AREA

CONDITION 5.0: MEAN ANNUAL FLOOD,
50-YR.SIMULATION CURRENT BURN

FIGURE 15



℄ OUTLET WORKS
℄ SPILLWAY
1400
1800
2200
2400
3000
4000
5000
6000
108
107
124
123
10ft - 12ft
12ft - 20ft
20ft - 30ft
30ft - 40ft
40ft - 50ft
50ft - 55ft
50ft - 30ft

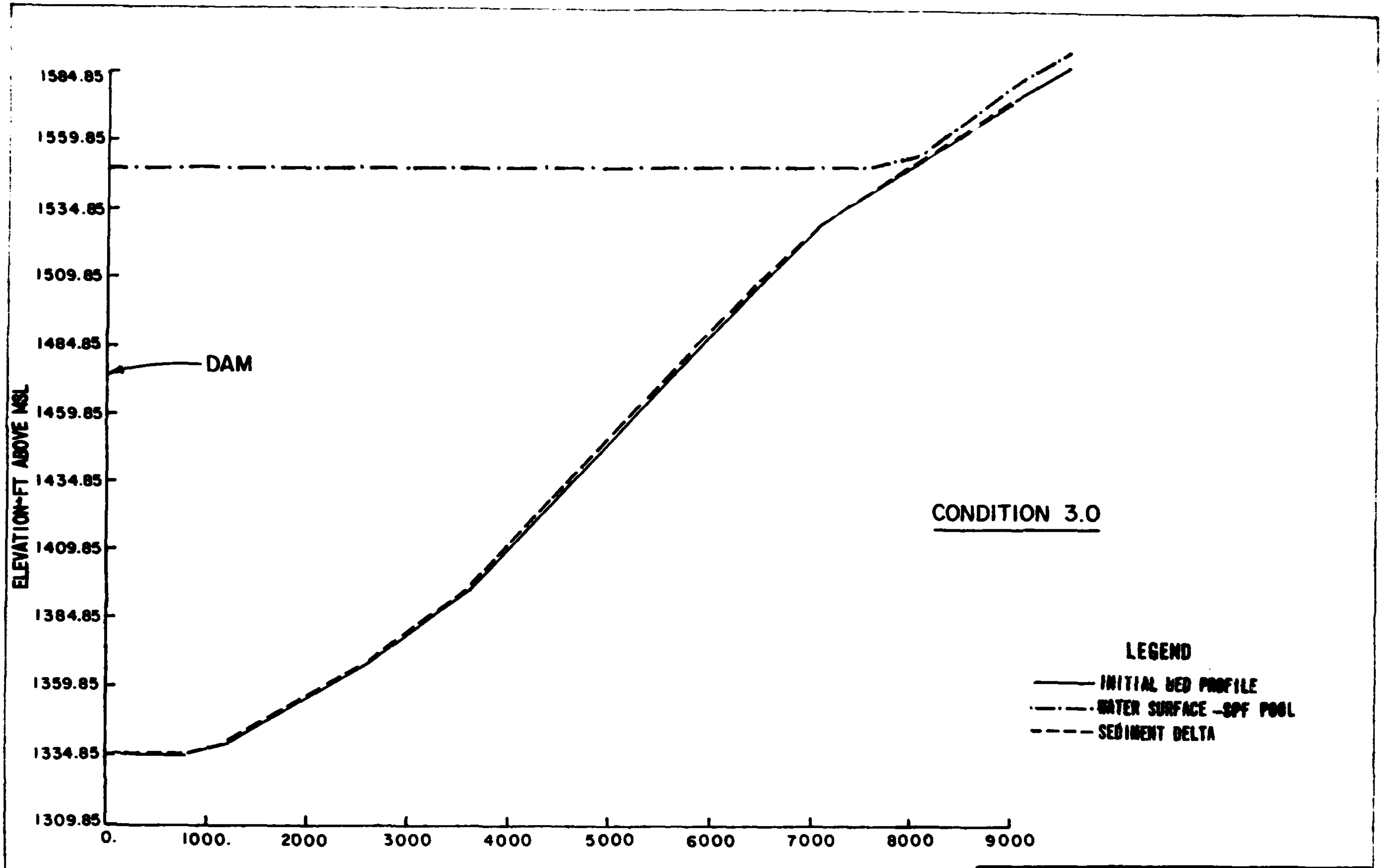


UPPER SANTA ANA RIVER
TWO-DIMENSIONAL GROUNDWATER AND SEDIMENT MODELING STUDIES

SPATIAL DISTRIBUTION OF SEDIMENT DEPOSITS IN THE RESERVOIR AREA

CONDITION 5.1: MEAN ANNUAL FLOOD, 100-YR. EXTRAPOLATED SIMULATION, CURRENT BURN

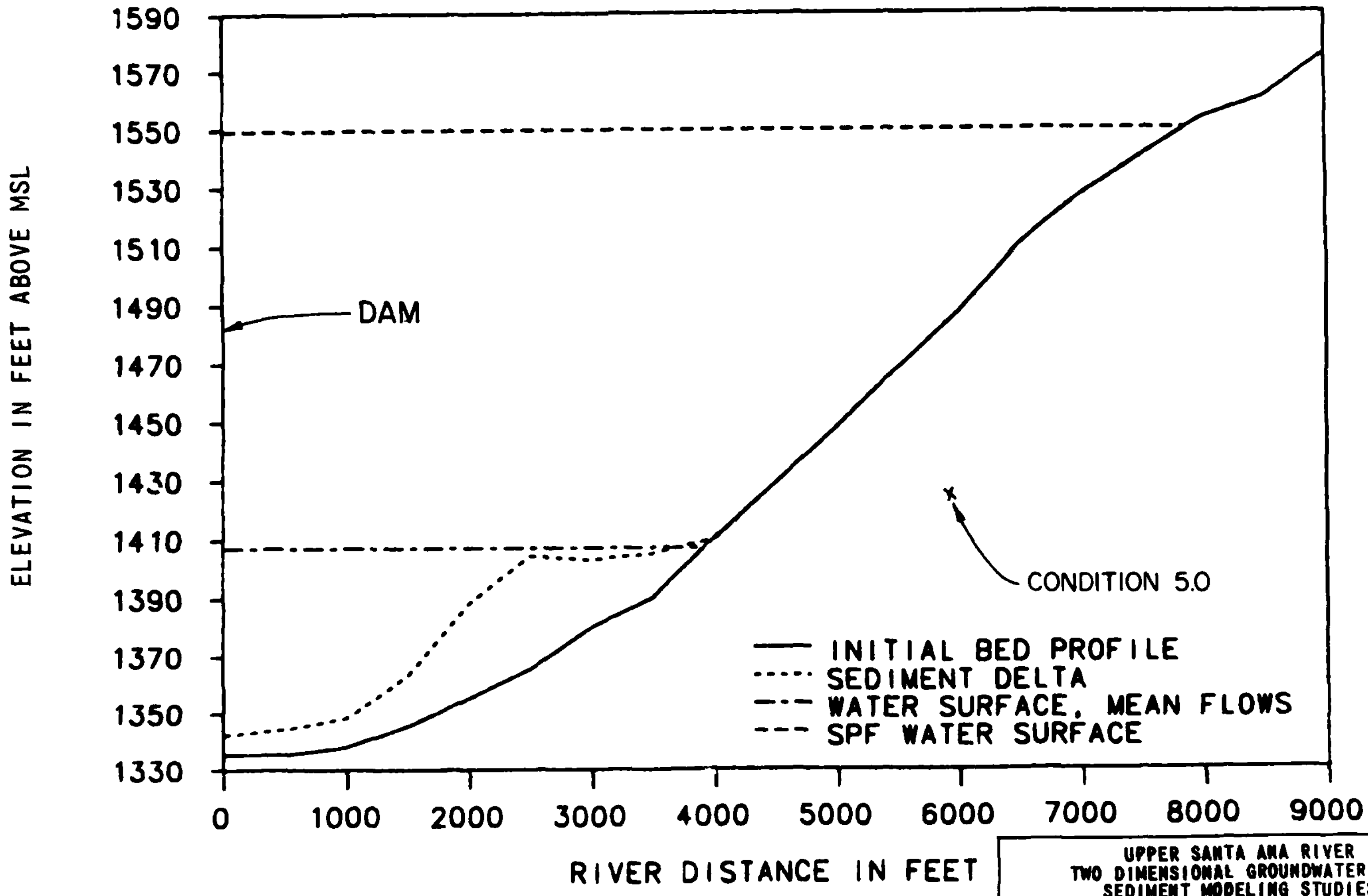
FIGURE 16



UPPER SANTA ANA RIVER
TWO DIMENSIONAL GROUNDWATER AND
SEDIMENT MODELING STUDIES

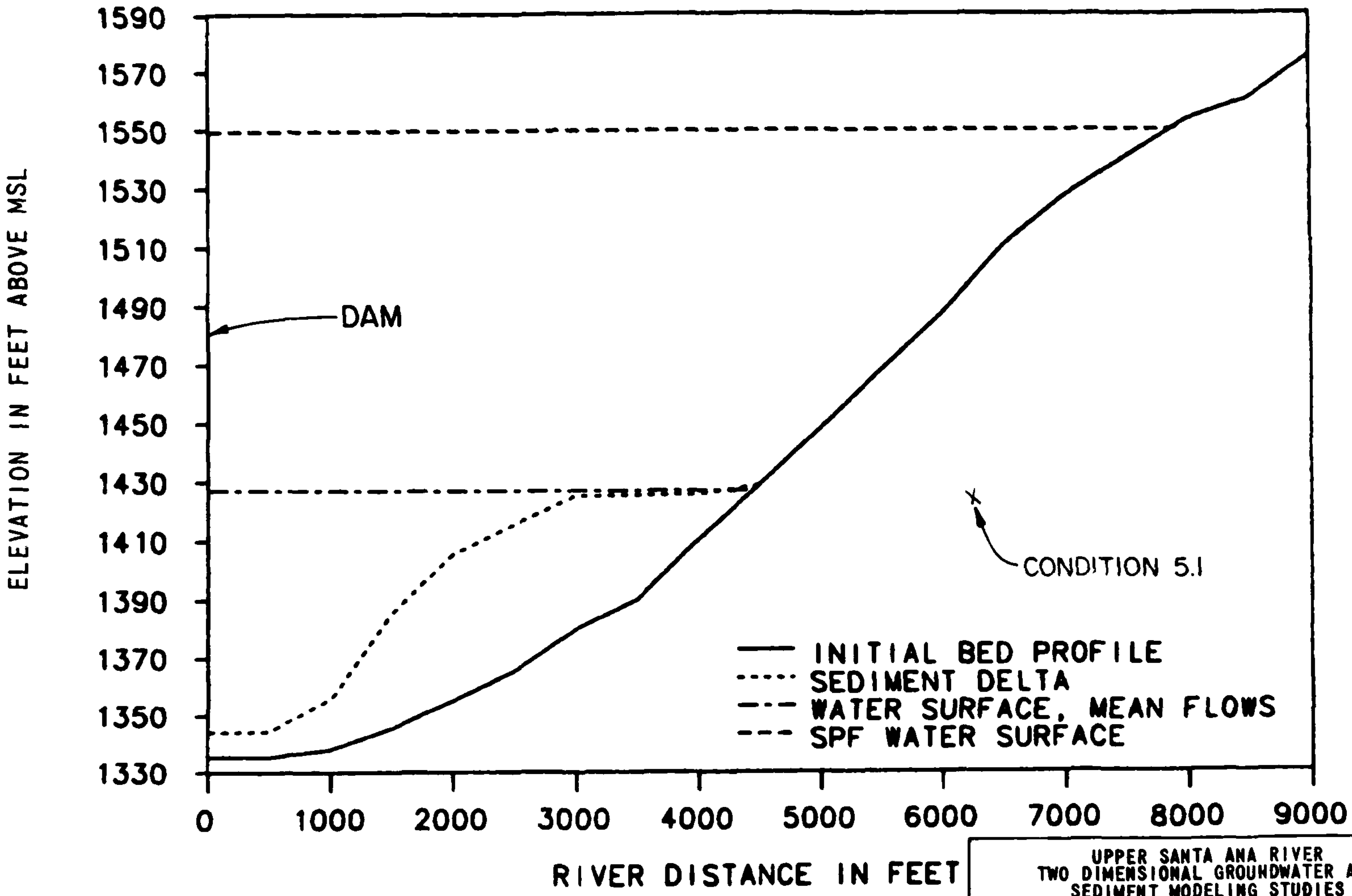
STANDARD PROJECT FLOOD DELTA
WITH CURRENT BURN WATERSHED

FIGURE 17



UPPER SANTA ANA RIVER
TWO DIMENSIONAL GROUNDWATER AND
SEDIMENT MODELING STUDIES

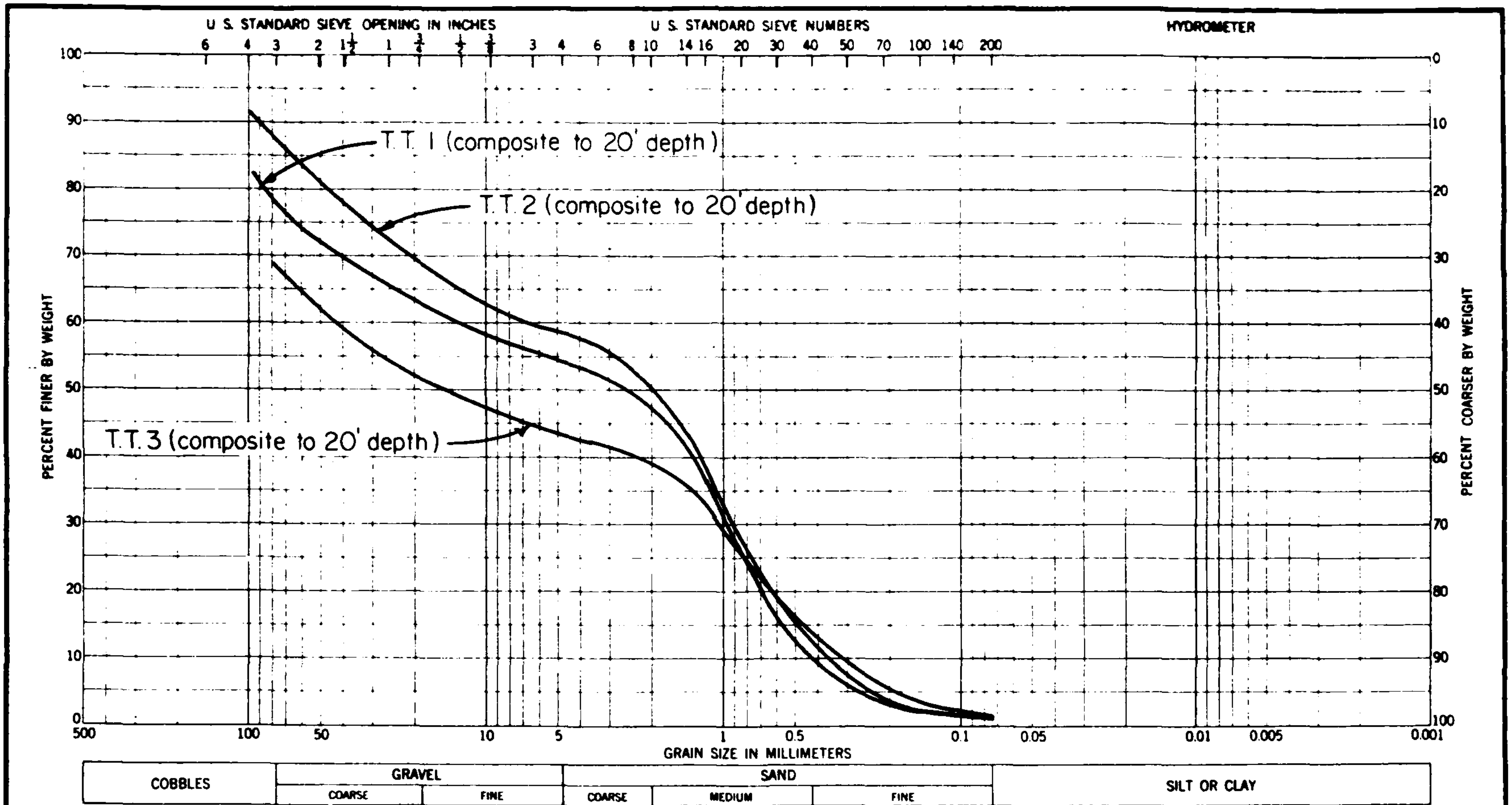
50 YR. DELTA MEAN ANNUAL FLOW
WITH CURRENT BURN WATERSHED



UPPER SANTA ANA RIVER
TWO DIMENSIONAL GROUNDWATER AND
SEDIMENT MODELING STUDIES

100 YR. DELTA MEAN ANNUAL FLOW
WITH CURRENT BURN WATERSHED

FIGURE 19



Sample No.	Elev or Depth	Classification	Nat w %	LL	PL	PI

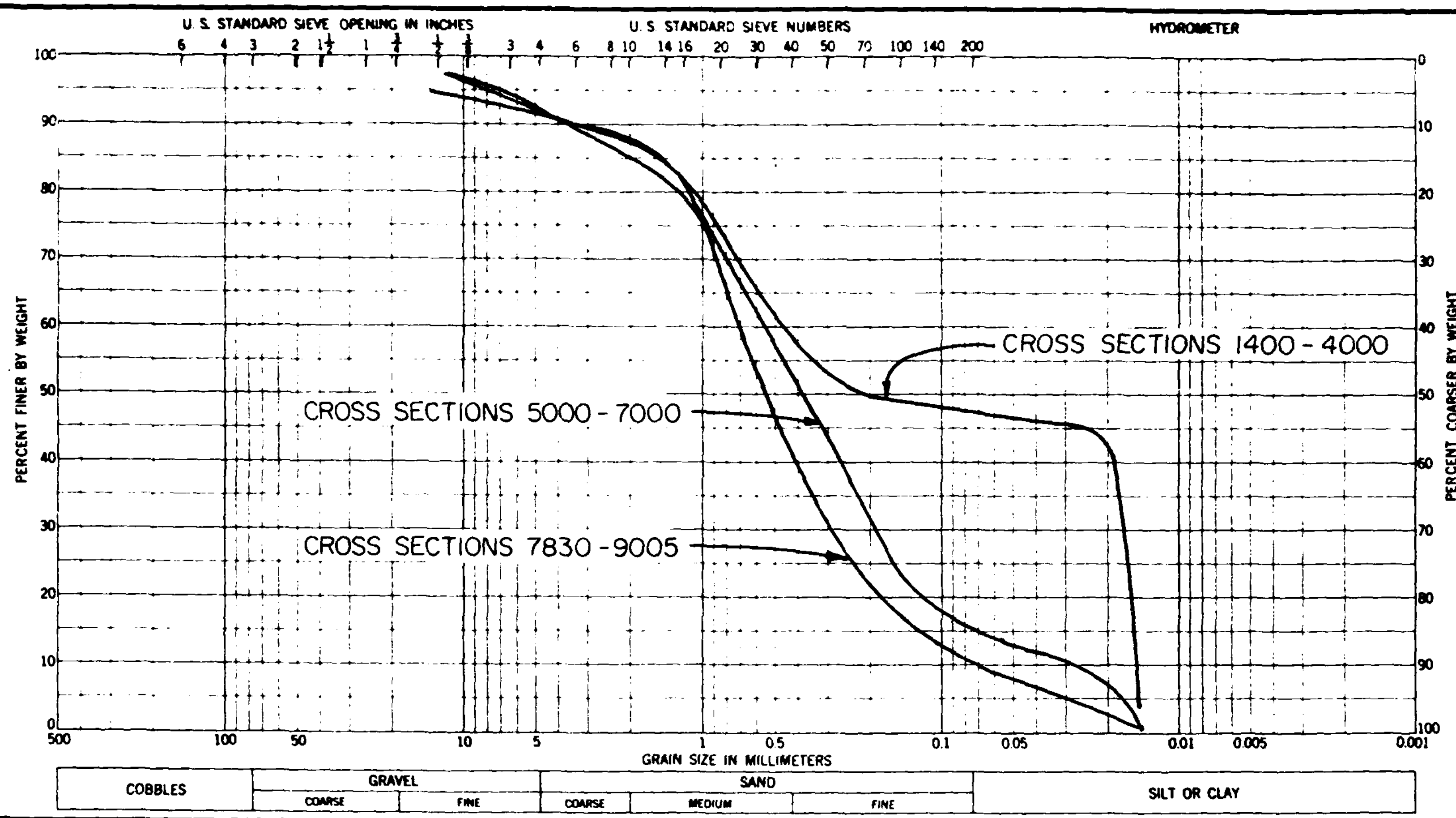
Project: MENTONE DAM
TEST TRENCHES 1, 2, & 3
COMPOSITE GRADATIONS

Date

GRADATION CURVES

ENG FORM 1 MAY 63 2087

FIGURE 20



Sample No.	Elev or Depth	Classification	Nat w %	LL	PL	PI

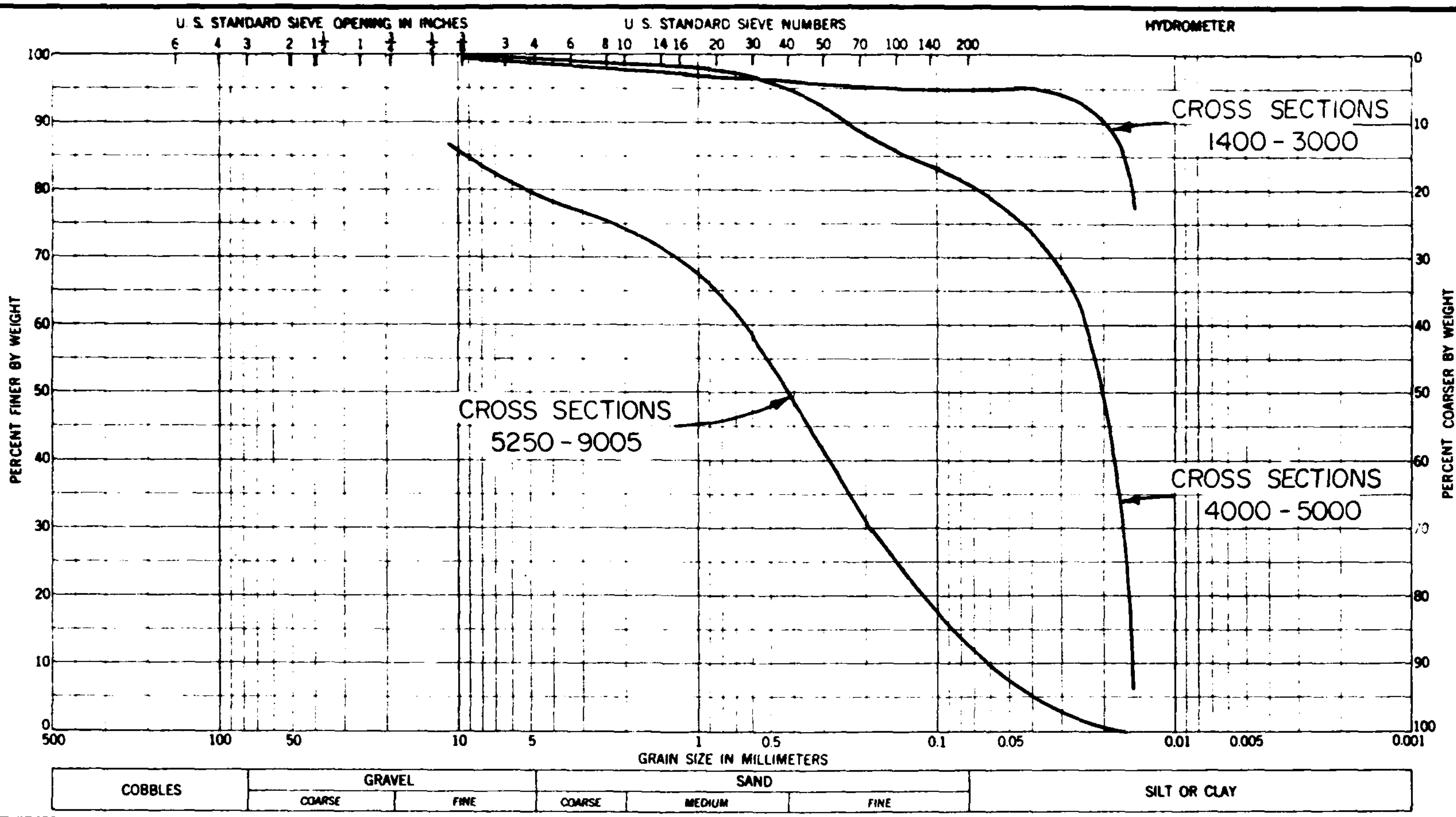
Project: MENTONE DAM
DEPOSITED MATERIALS
CONDITION 3

Date

GRADATION CURVES

ENG FORM 2087

FIGURE 21



Sample No.	Elev or Depth	Classification	Nat w %	LL	PL	PI

Project: MENTONE DAM
DEPOSITED MATERIALS
CONDITIONS 5.0 AND 5.1

Date

GRADATION CURVES

ENG FORM 1 MAY 63 2087

FIGURE 22

A HC2C

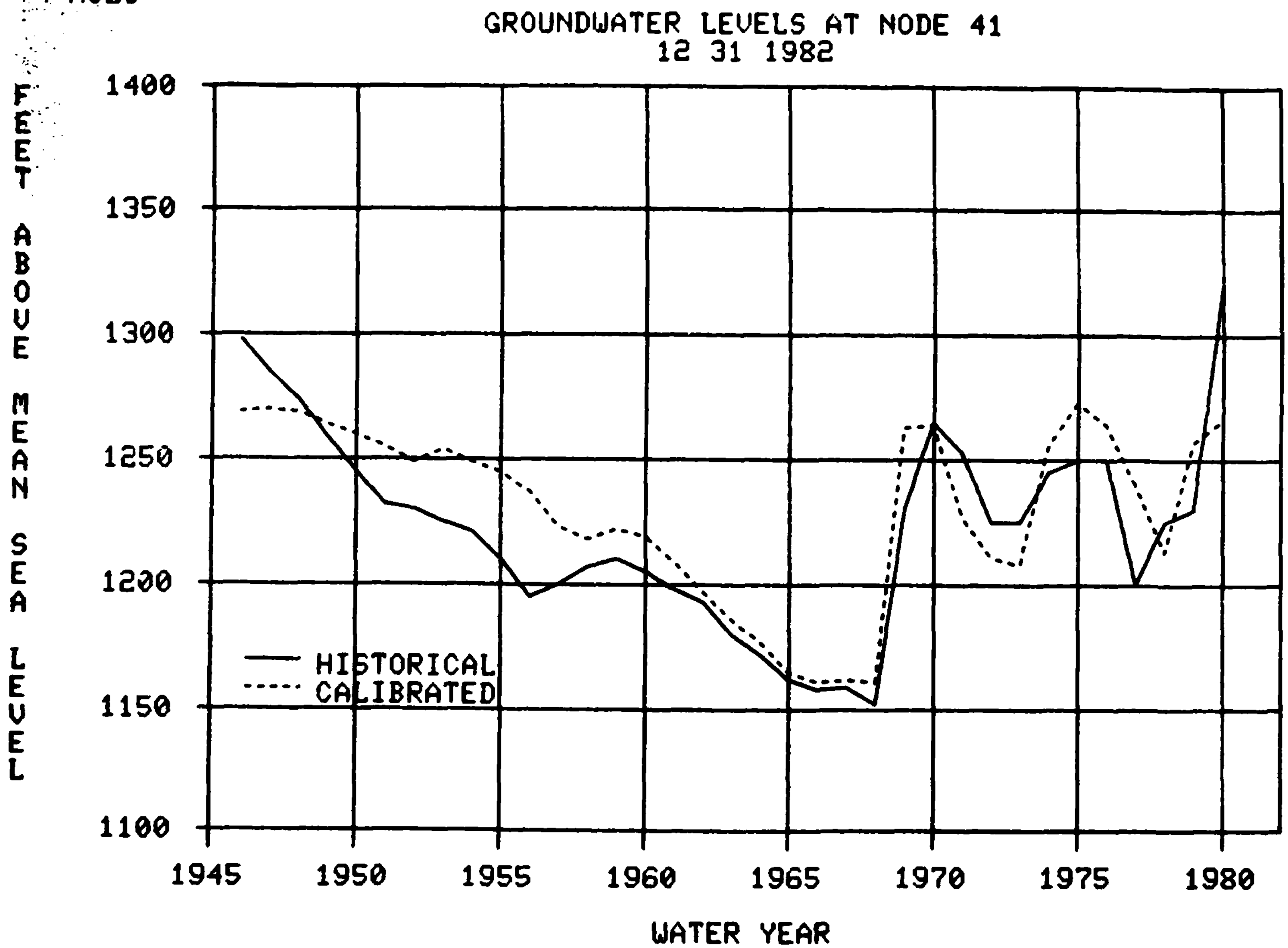


FIGURE 23

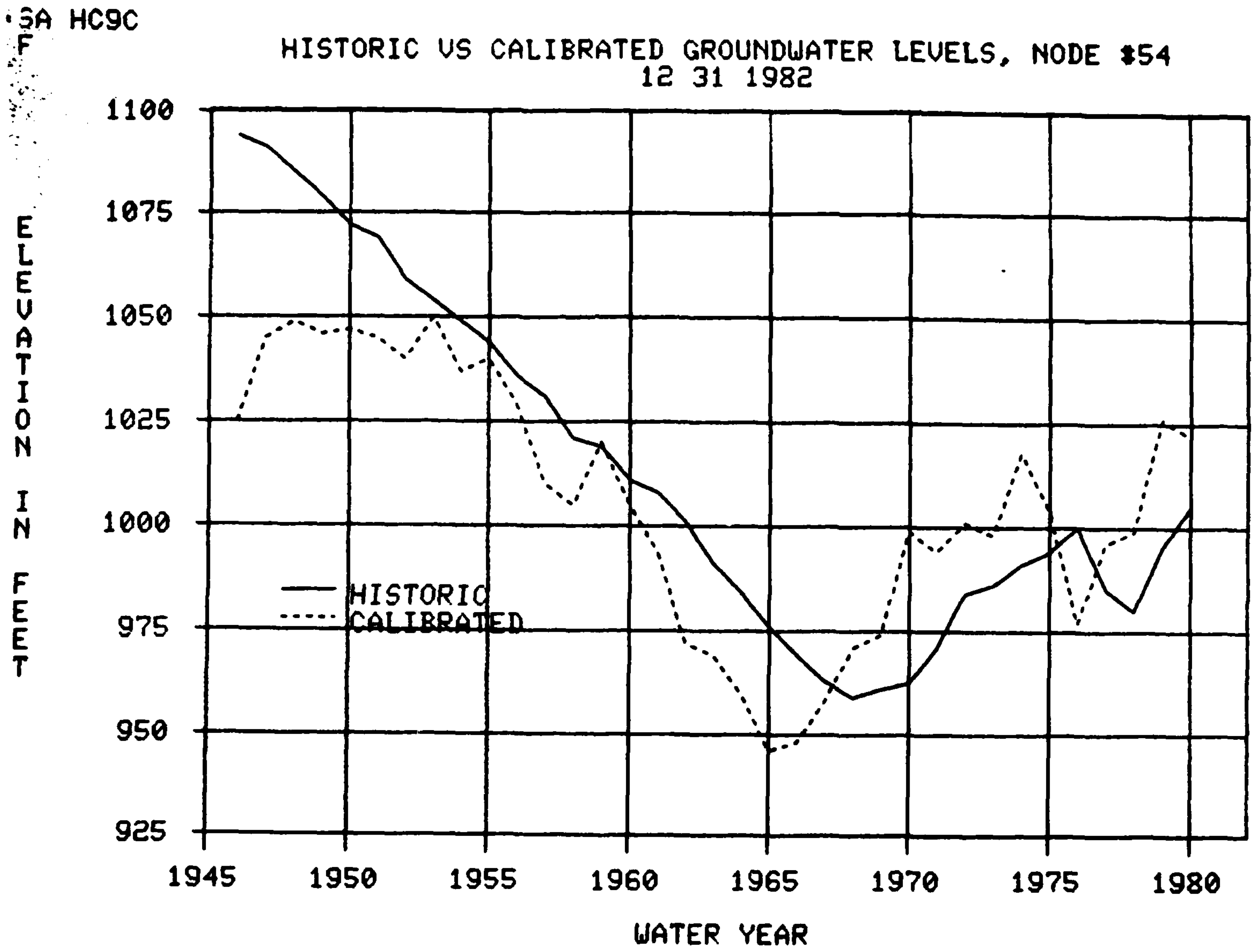
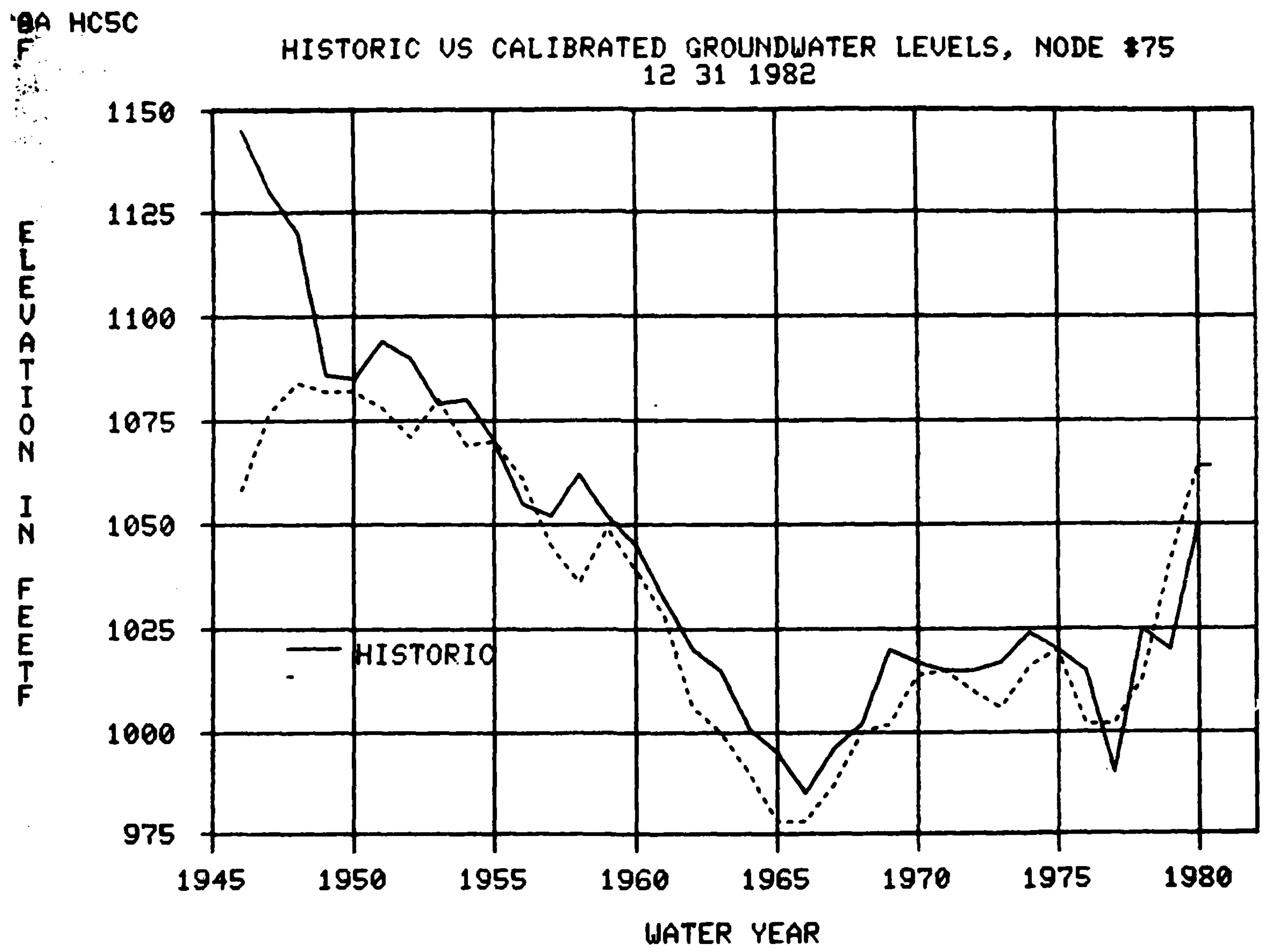

SA HC9C
F
HISTORIC VS CALIBRATED GROUNDWATER LEVELS, NODE #54
12 31 1982
ELEVATION IN FEET
1100
1075
1050
1025
1000
975
950
925
1945
1950
1955
1960
1965
1970
1975
1980
WATER YEAR
HISTORIC
CALIBRATED

FIGURE 24



'BA HC5C
F
HISTORIC VS CALIBRATED GROUNDWATER LEVELS, NODE #75
12 31 1982
ELEVATION IN FEETF
1150
1125
1100
1075
1050
1025
1000
975
1945
1950
1955
1960
1965
1970
1975
1980
WATER YEAR
HISTORIC

FIGURE 25

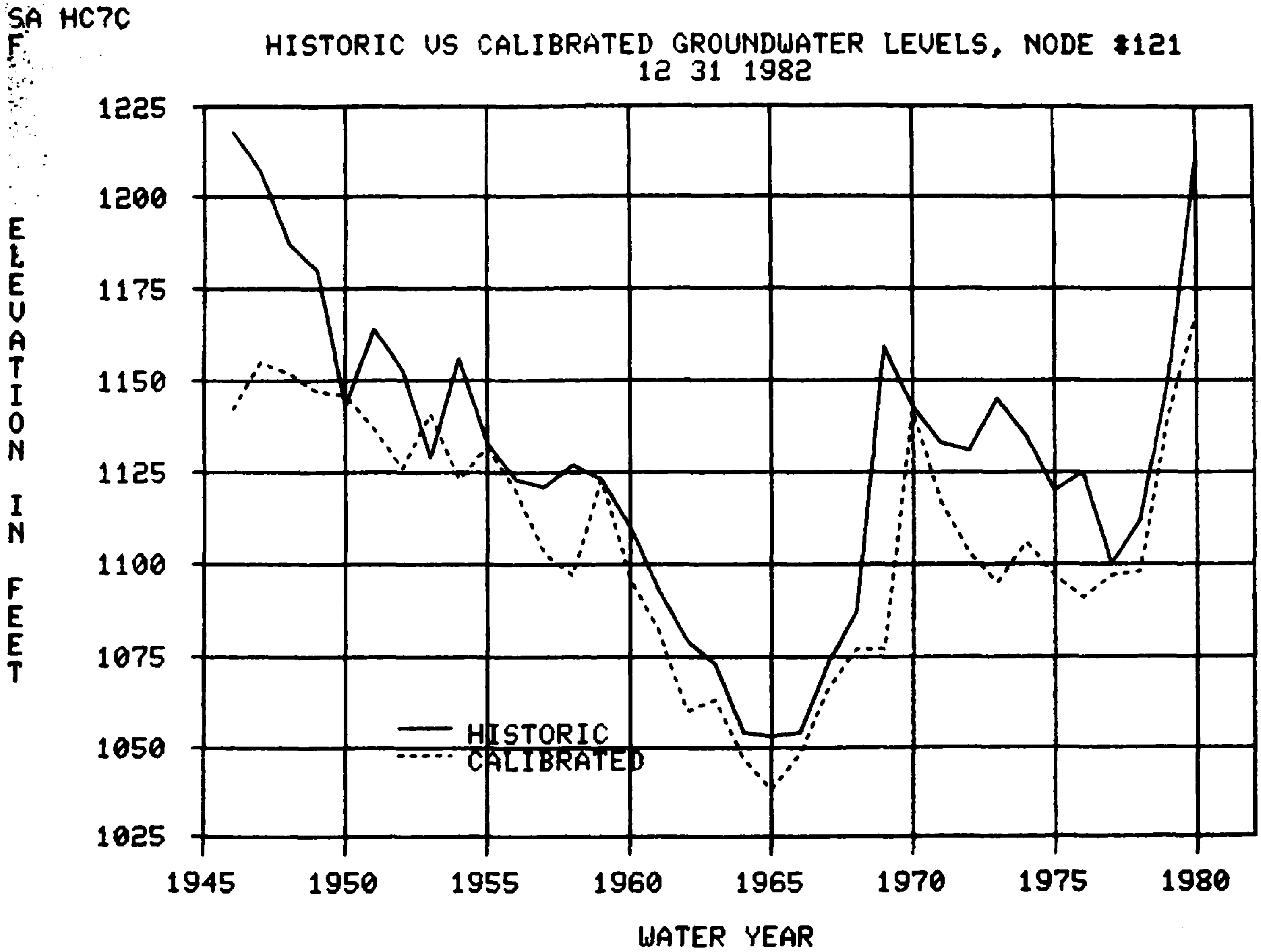
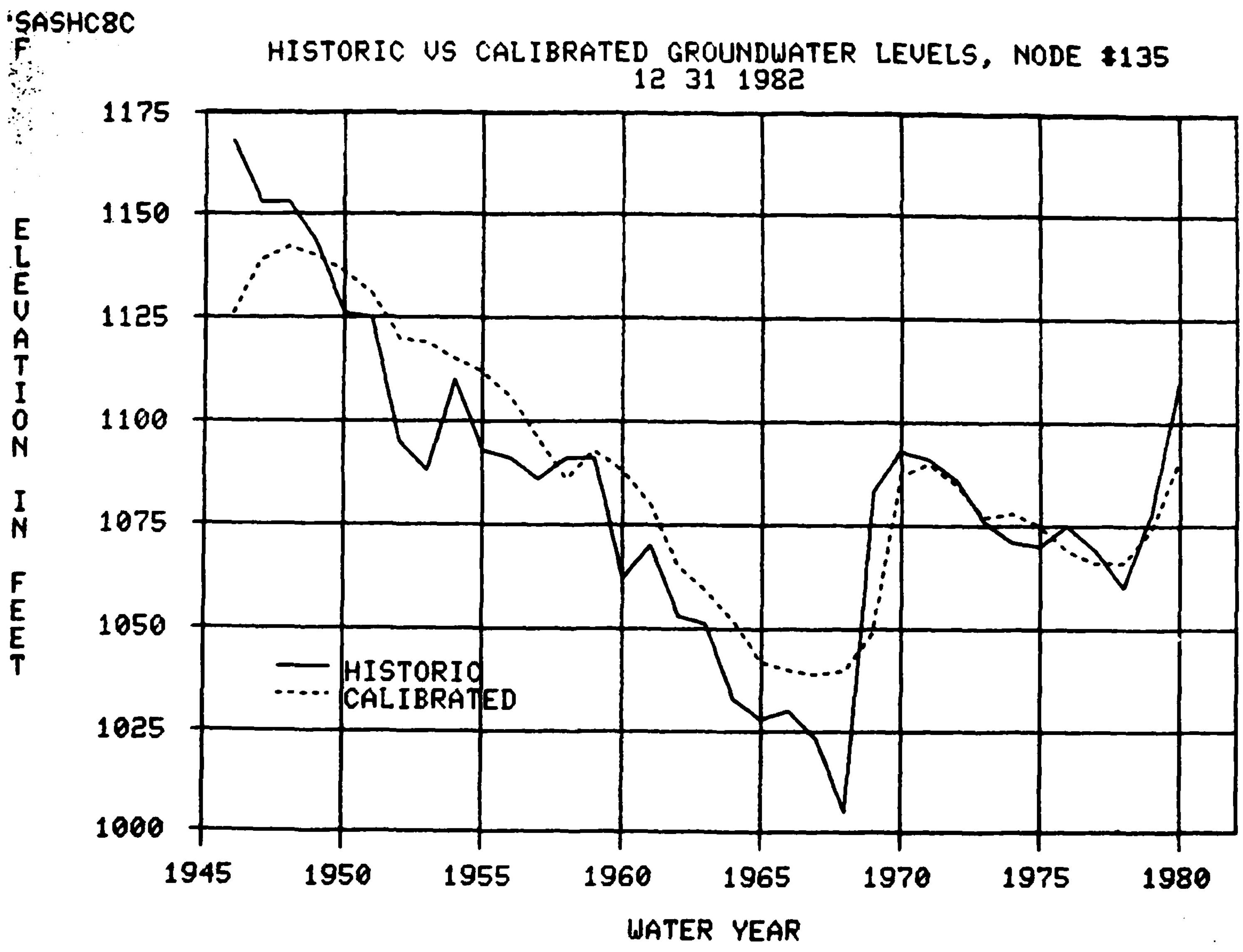
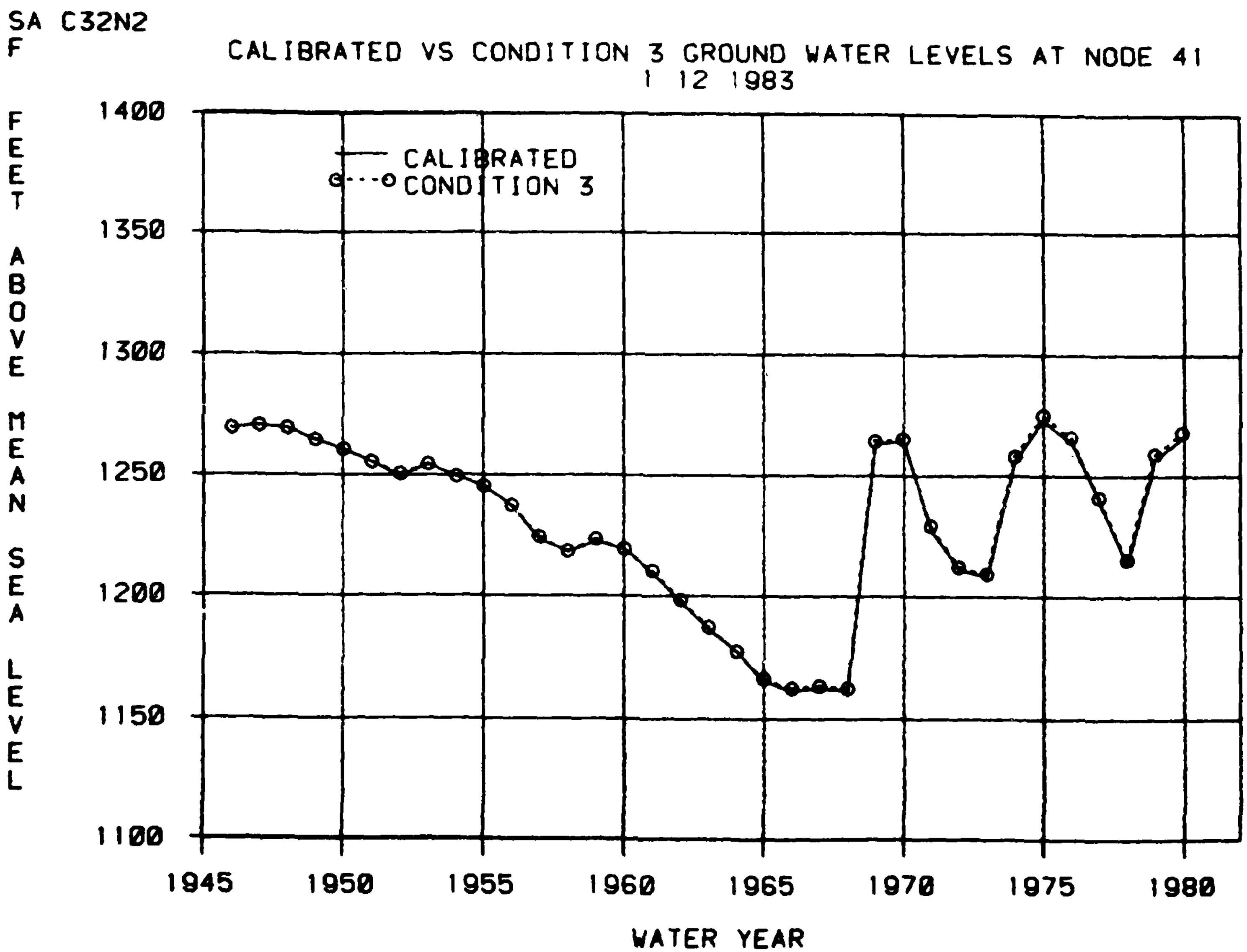

SA HC7C
HISTORIC VS CALIBRATED GROUNDWATER LEVELS, NODE #121
12 31 1982
ELEVATION IN FEET
1225
1200
1175
1150
1125
1100
1075
1050
1025
1945
1950
1955
1960
1965
1970
1975
1980
WATER YEAR
HISTORIC
CALIBRATED

FIGURE 26



SASHC8C
HISTORIC VS CALIBRATED GROUNDWATER LEVELS, NODE #135
12 31 1982
ELEVATION IN FEET
1175
1150
1125
1100
1075
1050
1025
1000
1945
1950
1955
1960
1965
1970
1975
1980
WATER YEAR
HISTORIC
CALIBRATED

FIGURE 27



SA C32N2
CALIBRATED VS CONDITION 3 GROUND WATER LEVELS AT NODE 41
1 12 1983
FEET ABOVE MEAN SEA LEVEL
1400
1350
1300
1250
1200
1150
1100
CALIBRATED
CONDITION 3
1945
1950
1955
1960
1965
1970
1975
1980
WATER YEAR

FIGURE 28

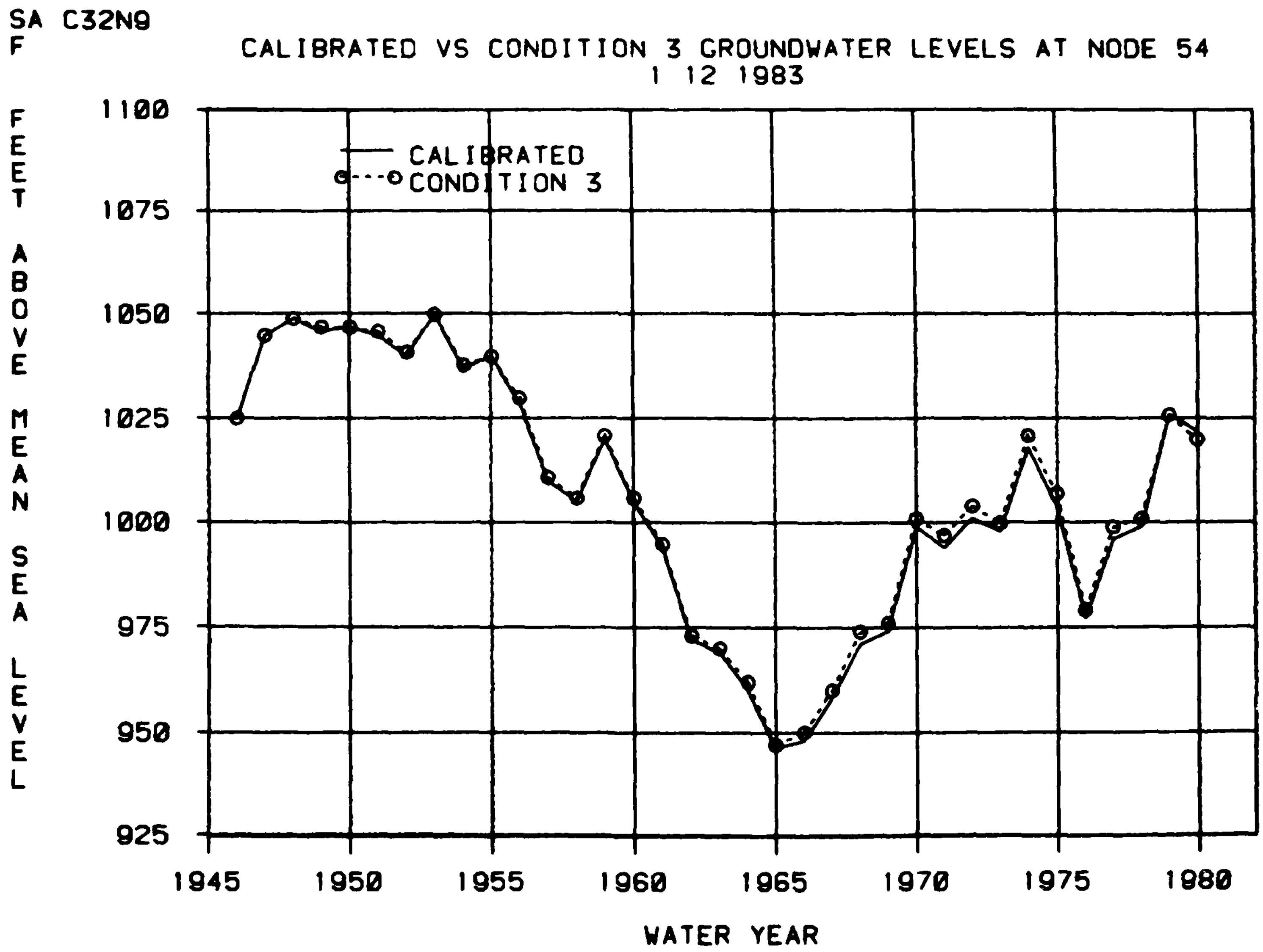

SA C32N9
F
CALIBRATED VS CONDITION 3 GROUNDWATER LEVELS AT NODE 54
1 12 1983
FEET ABOVE MEAN SEA LEVEL
1100
1075
1050
1025
1000
975
950
925
CALIBRATED
CONDITION 3
1945
1950
1955
1960
1965
1970
1975
1980
WATER YEAR

FIGURE 29

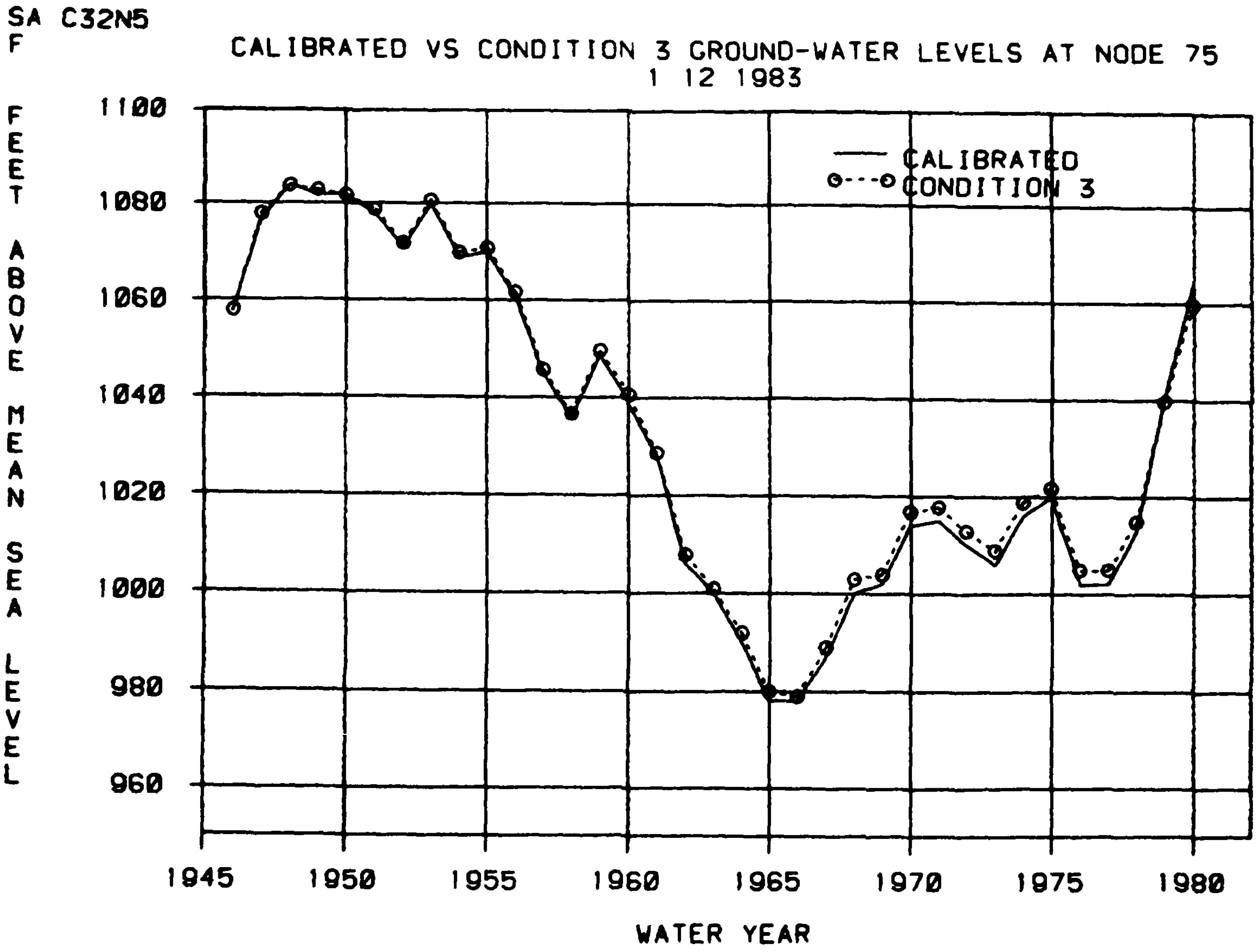
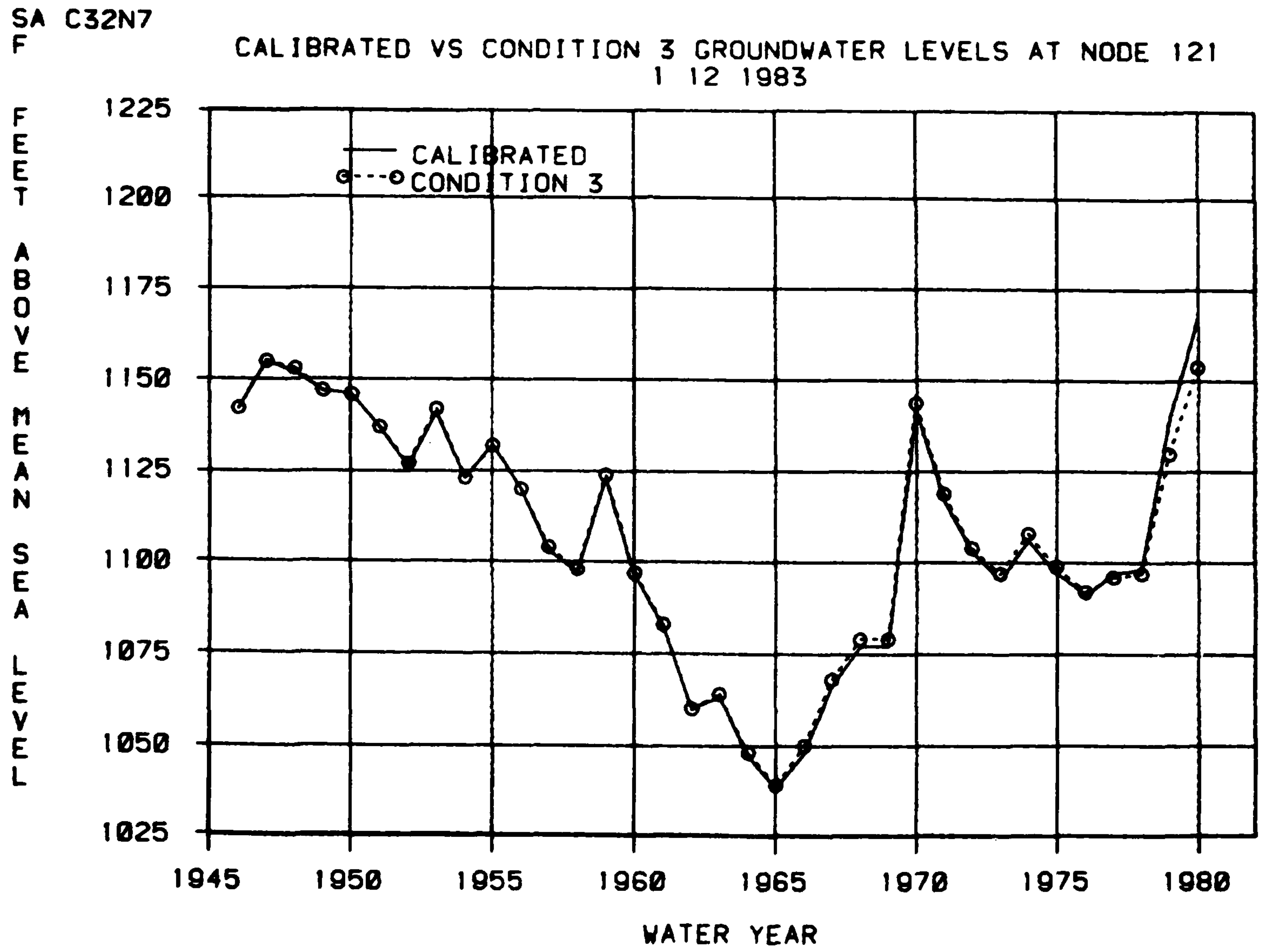

SA C32N5
CALIBRATED VS CONDITION 3 GROUND-WATER LEVELS AT NODE 75
1 12 1983
F FEET ABOVE MEAN SEA LEVEL
1100
1080
1060
1040
1020
1000
980
960
CALIBRATED
CONDITION 3
1945
1950
1955
1960
1965
1970
1975
1980
WATER YEAR

FIGURE 30



SA C32N7
F
CALIBRATED VS CONDITION 3 GROUNDWATER LEVELS AT NODE 121
1 12 1983
FEET ABOVE MEAN SEA LEVEL
1225
1200
1175
1150
1125
1100
1075
1050
1025
CALIBRATED
CONDITION 3
1945
1950
1955
1960
1965
1970
1975
1980
WATER YEAR

FIGURE 31

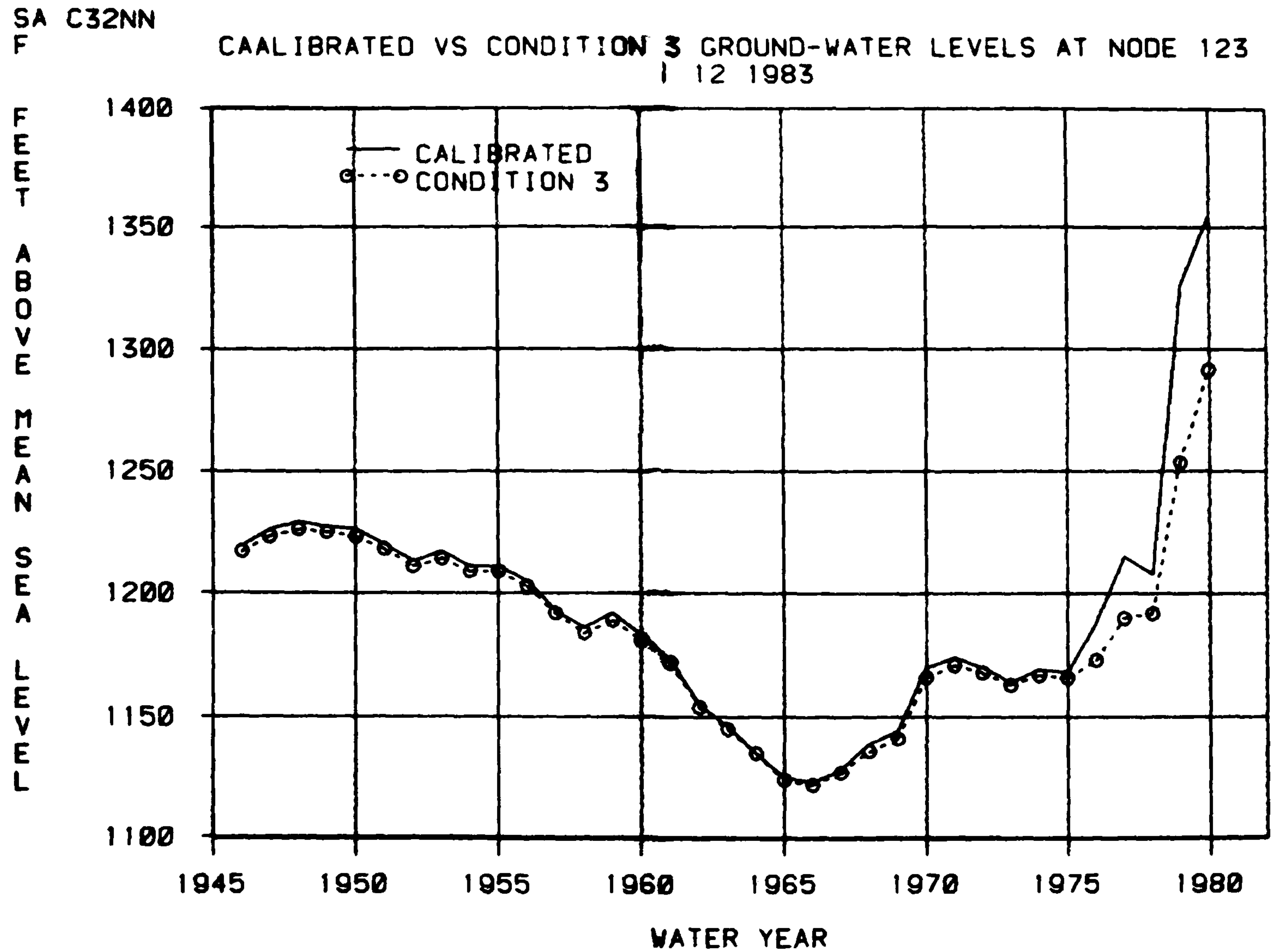

SA C32NN
CAALIBRATED VS CONDITION 3 GROUND-WATER LEVELS AT NODE 123
1 12 1983
CALIBRATED
CONDITION 3
FEET ABOVE MEAN SEA LEVEL
1400
1350
1300
1250
1200
1150
1100
1945
1950
1955
1960
1965
1970
1975
1980
WATER YEAR

FIGURE 32

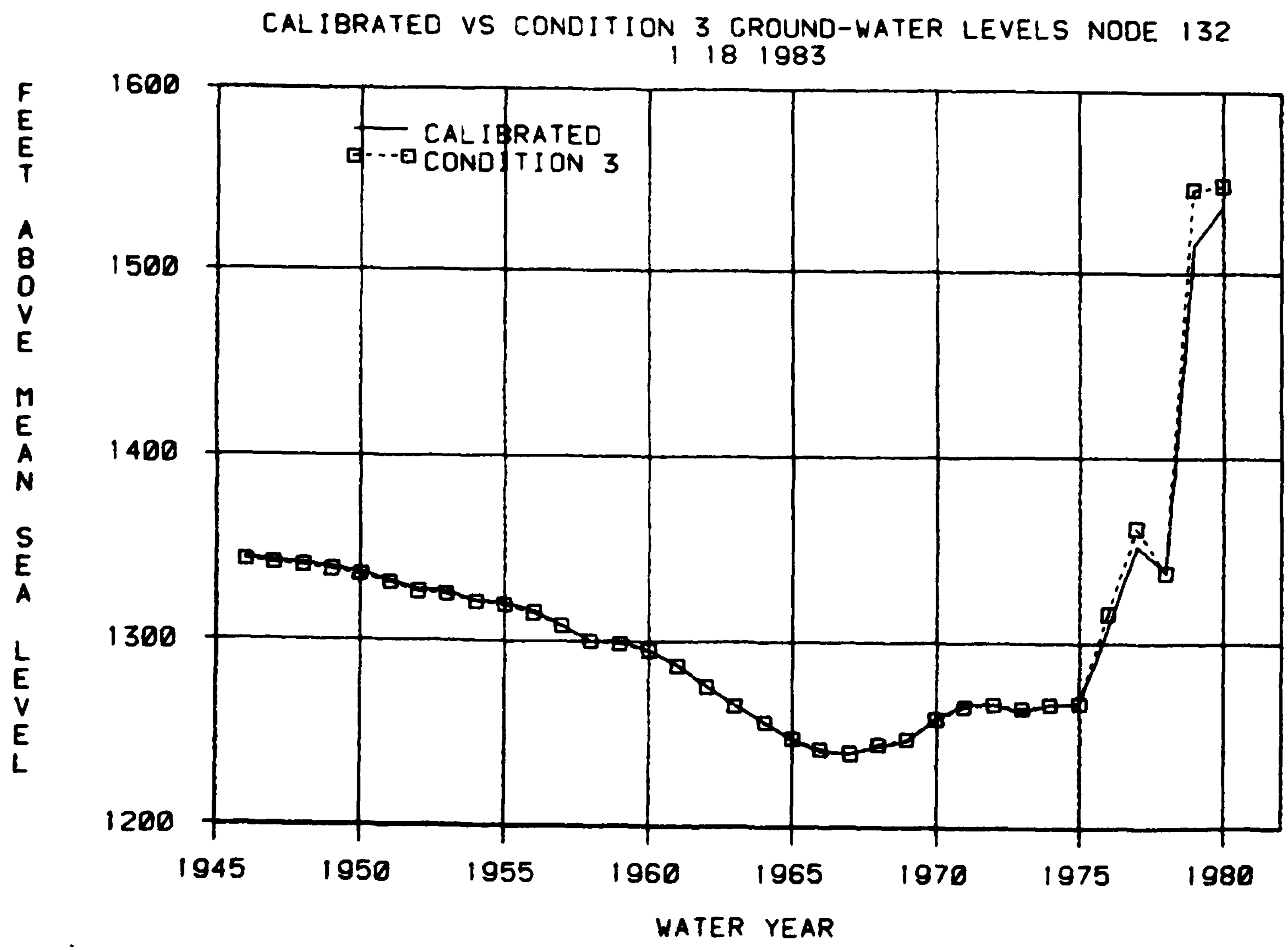
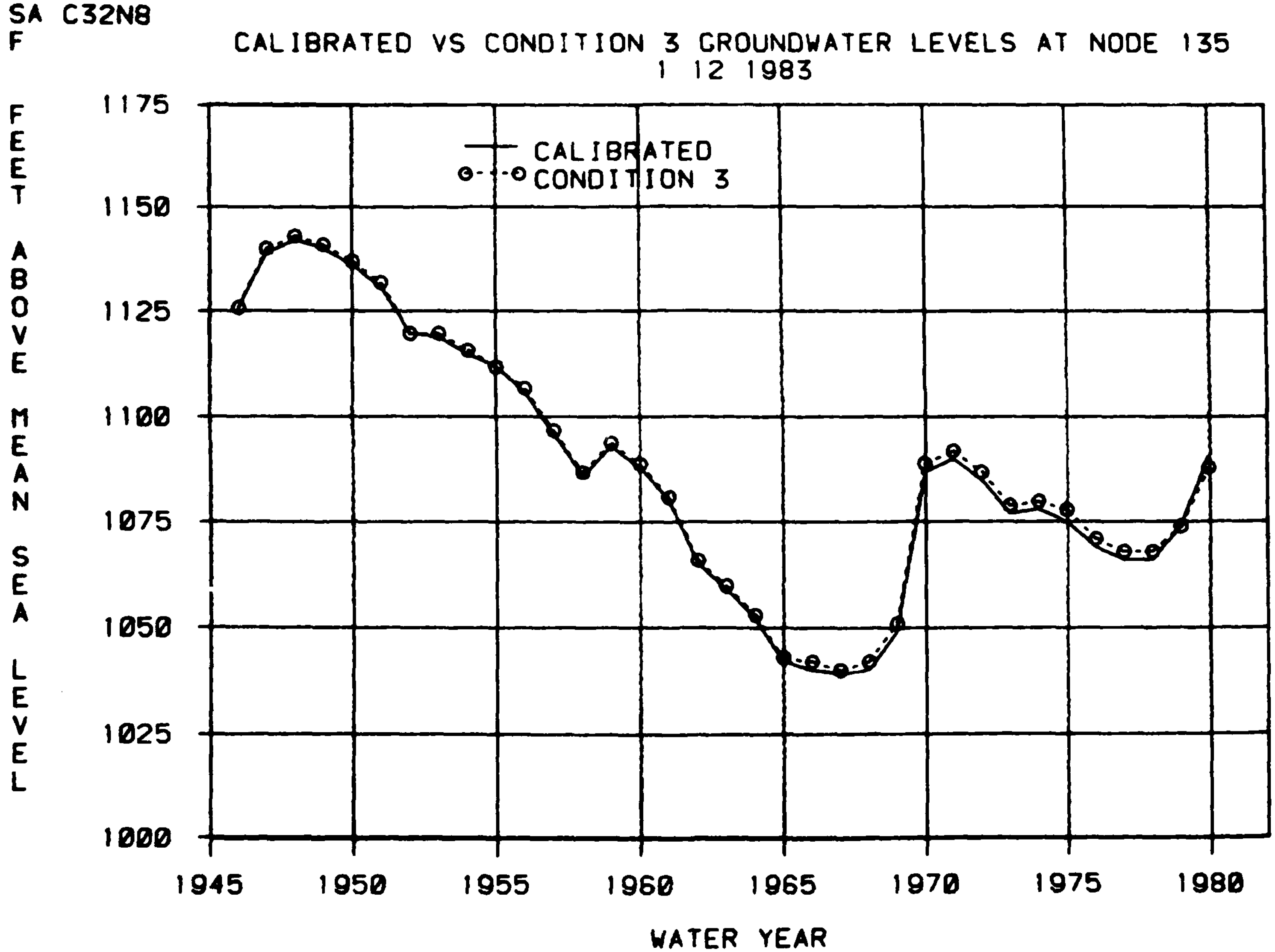
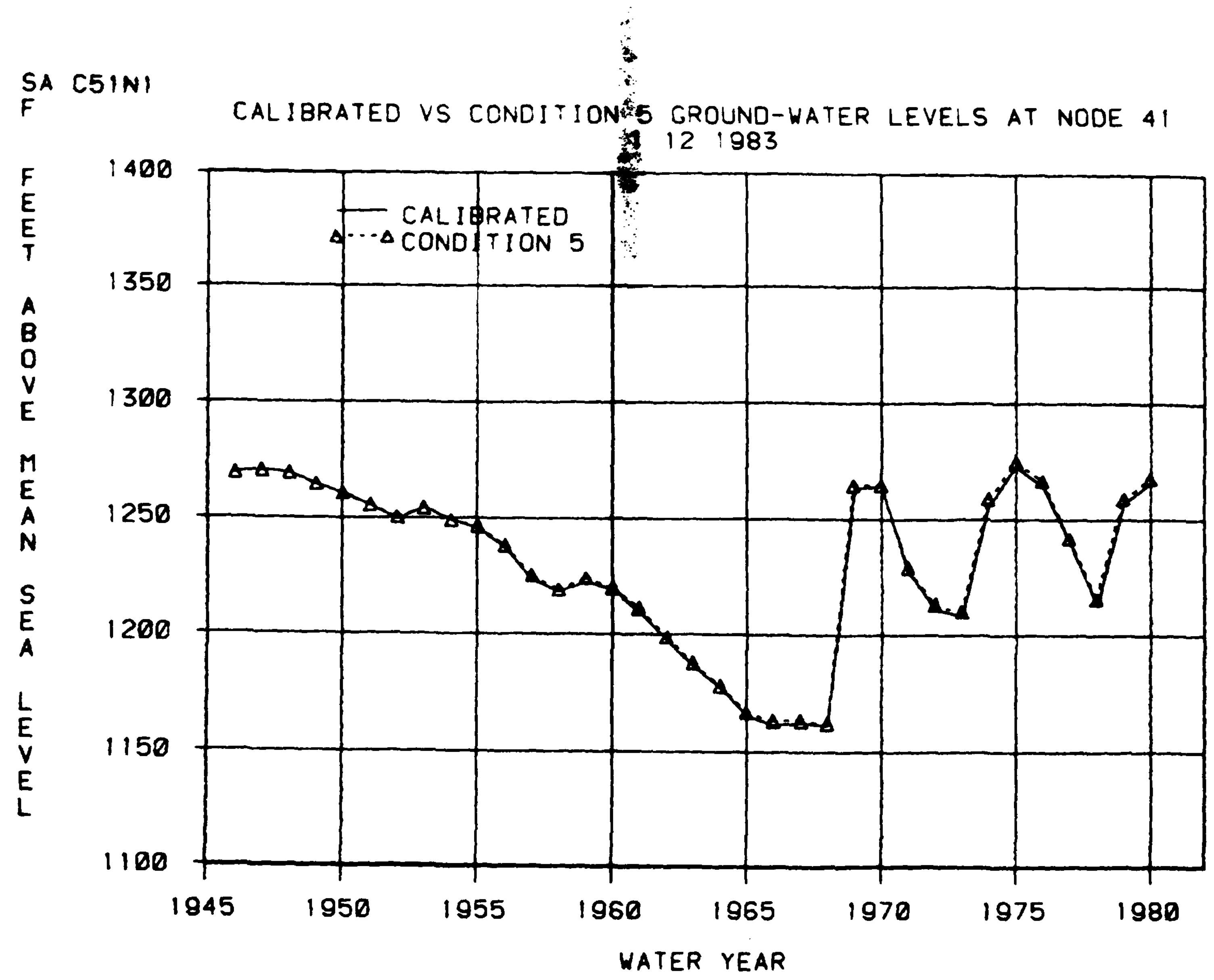

CALIBRATED VS CONDITION 3 GROUND-WATER LEVELS NODE 132
1 18 1983
CALIBRATED
CONDITION 3
FEET ABOVE MEAN SEA LEVEL
1600
1500
1400
1300
1200
1945
1950
1955
1960
1965
1970
1975
1980
WATER YEAR

FIGURE 33



SA C32N8
F
CALIBRATED VS CONDITION 3 GROUNDWATER LEVELS AT NODE 135
1 12 1983
FEET ABOVE MEAN SEA LEVEL
1175
1150
1125
1100
1075
1050
1025
1000
CALIBRATED
CONDITION 3
1945
1950
1955
1960
1965
1970
1975
1980
WATER YEAR

FIGURE 34



SA C51N1
CALIBRATED VS CONDITION 5 GROUND-WATER LEVELS AT NODE 41
12 1983
FEET ABOVE MEAN SEA LEVEL
1400
1350
1300
1250
1200
1150
1100
CALIBRATED
CONDITION 5
1945
1950
1955
1960
1965
1970
1975
1980
WATER YEAR

FIGURE 35

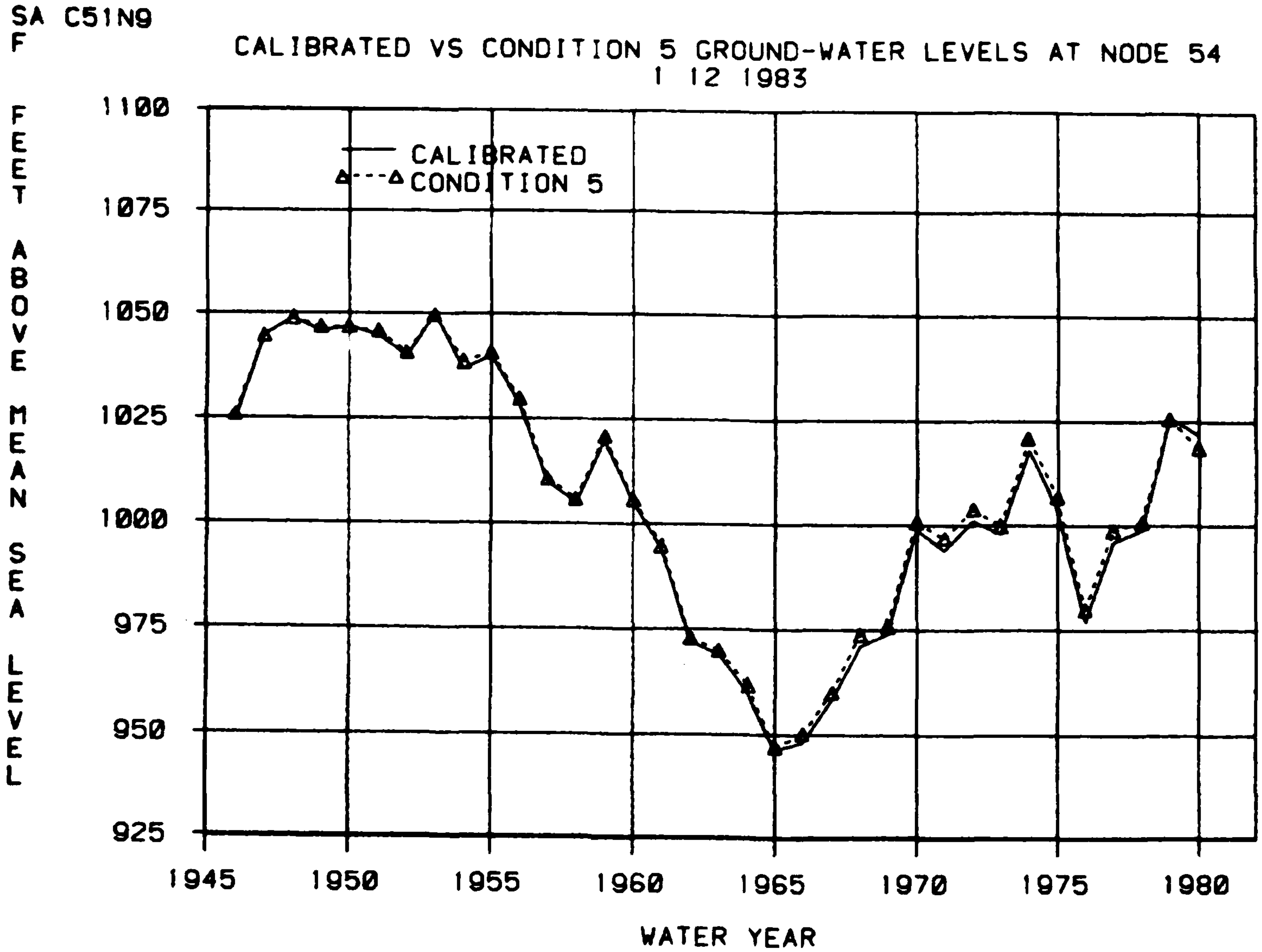

SA C51N9
CALIBRATED VS CONDITION 5 GROUND-WATER LEVELS AT NODE 54
1 12 1983
FEET ABOVE MEAN SEA LEVEL
1100
1075
1050
1025
1000
975
950
925
CALIBRATED
CONDITION 5
1945
1950
1955
1960
1965
1970
1975
1980
WATER YEAR

FIGURE 36

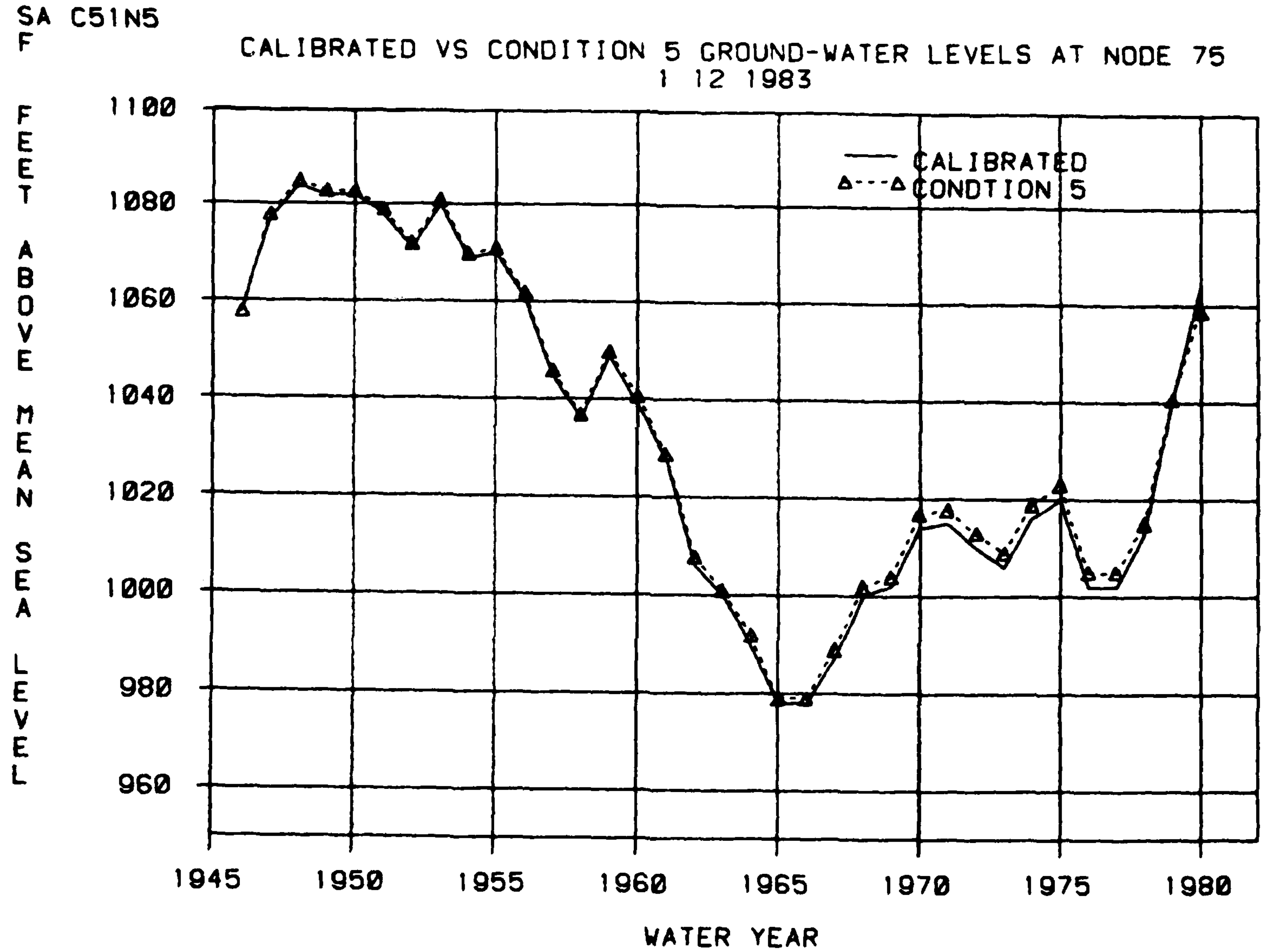
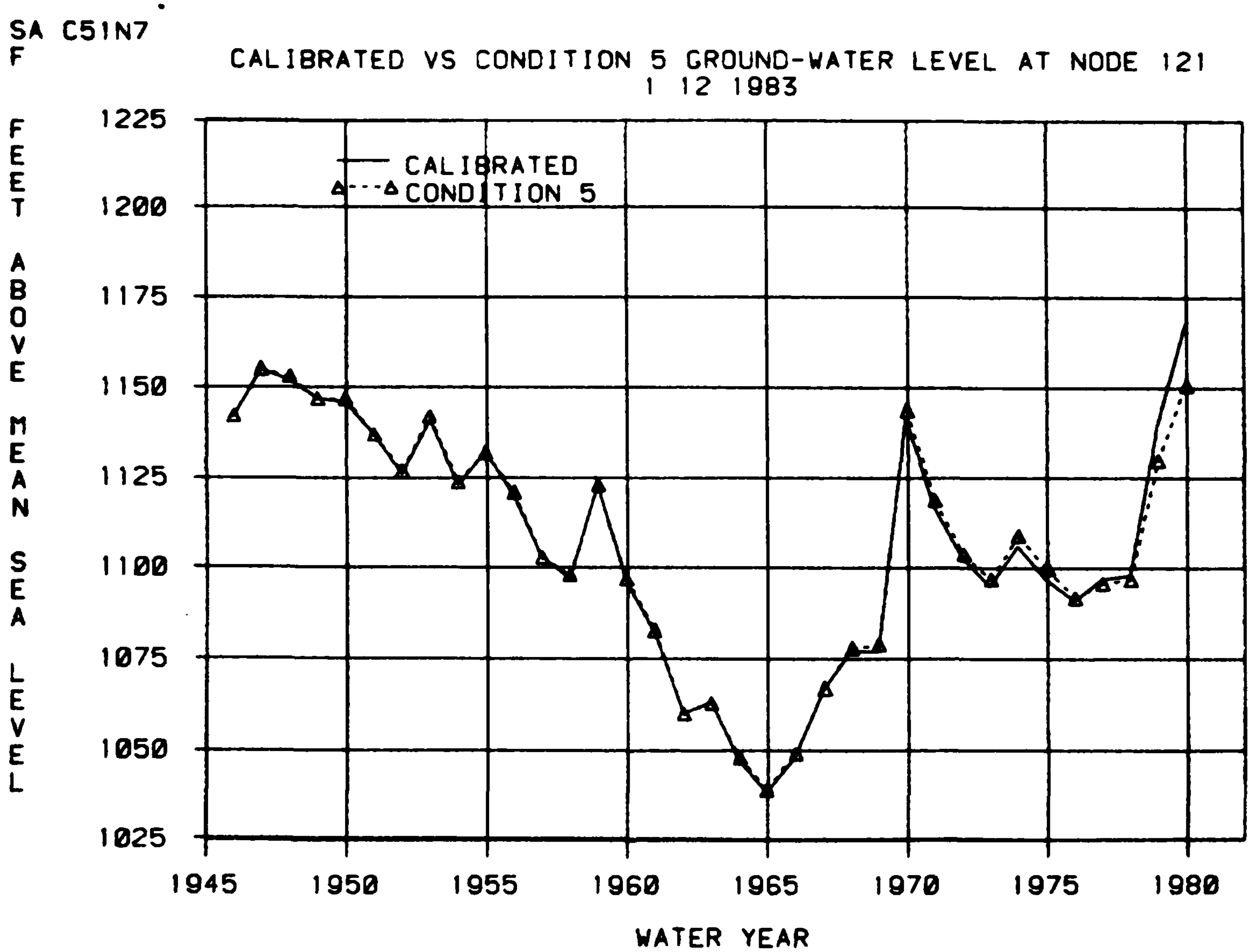

SA C51N5
F
CALIBRATED VS CONDITION 5 GROUND-WATER LEVELS AT NODE 75
1 12 1983
FEET ABOVE MEAN SEA LEVEL
1100
1080
1060
1040
1020
1000
980
960
CALIBRATED
CONDTION 5
1945
1950
1955
1960
1965
1970
1975
1980
WATER YEAR

FIGURE 37



SA C51N7
CALIBRATED VS CONDITION 5 GROUND-WATER LEVEL AT NODE 121
1 12 1983
FEET ABOVE MEAN SEA LEVEL
1225
1200
1175
1150
1125
1100
1075
1050
1025
CALIBRATED
CONDITION 5
1945
1950
1955
1960
1965
1970
1975
1980
WATER YEAR

FIGURE 38

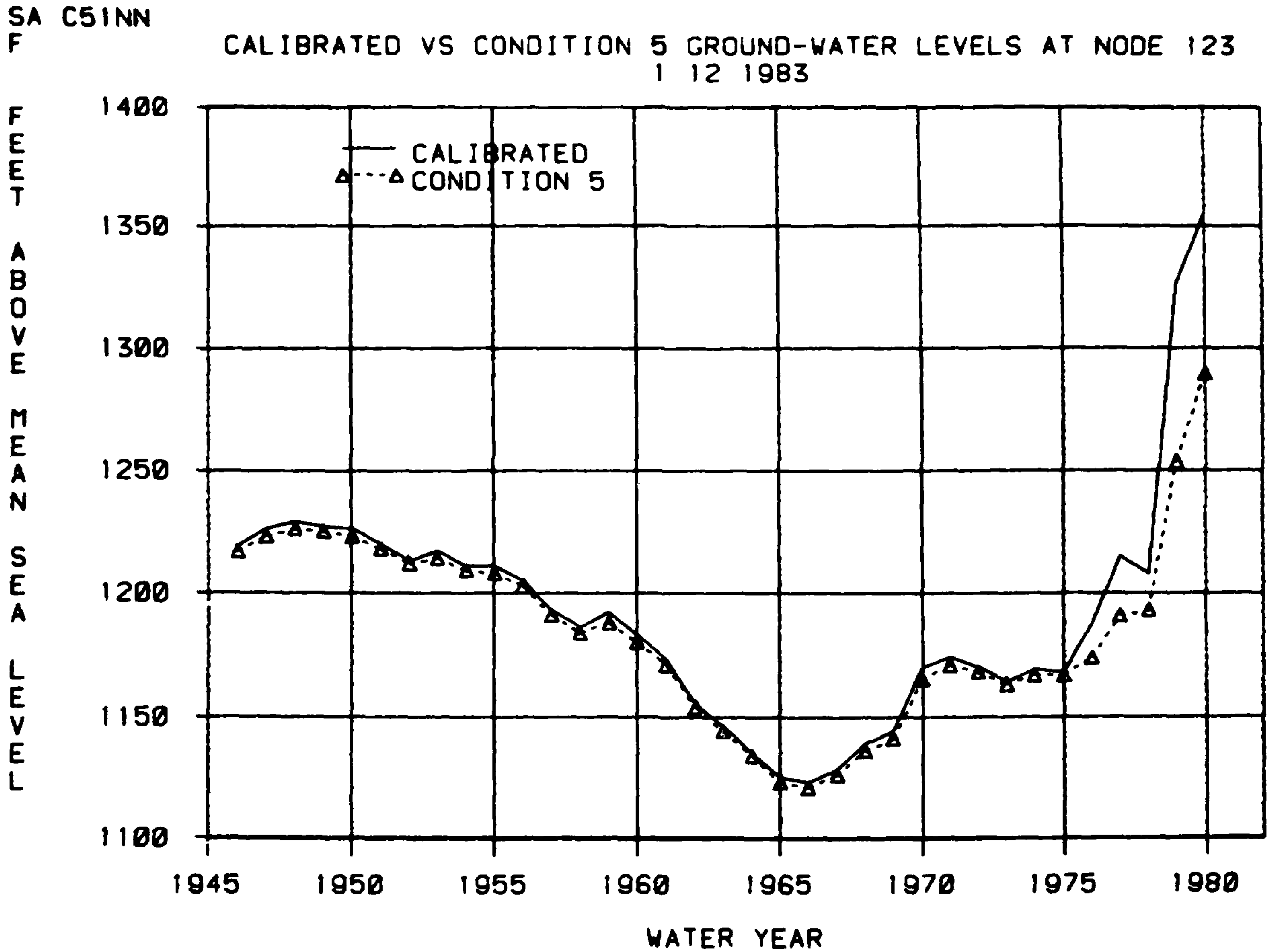
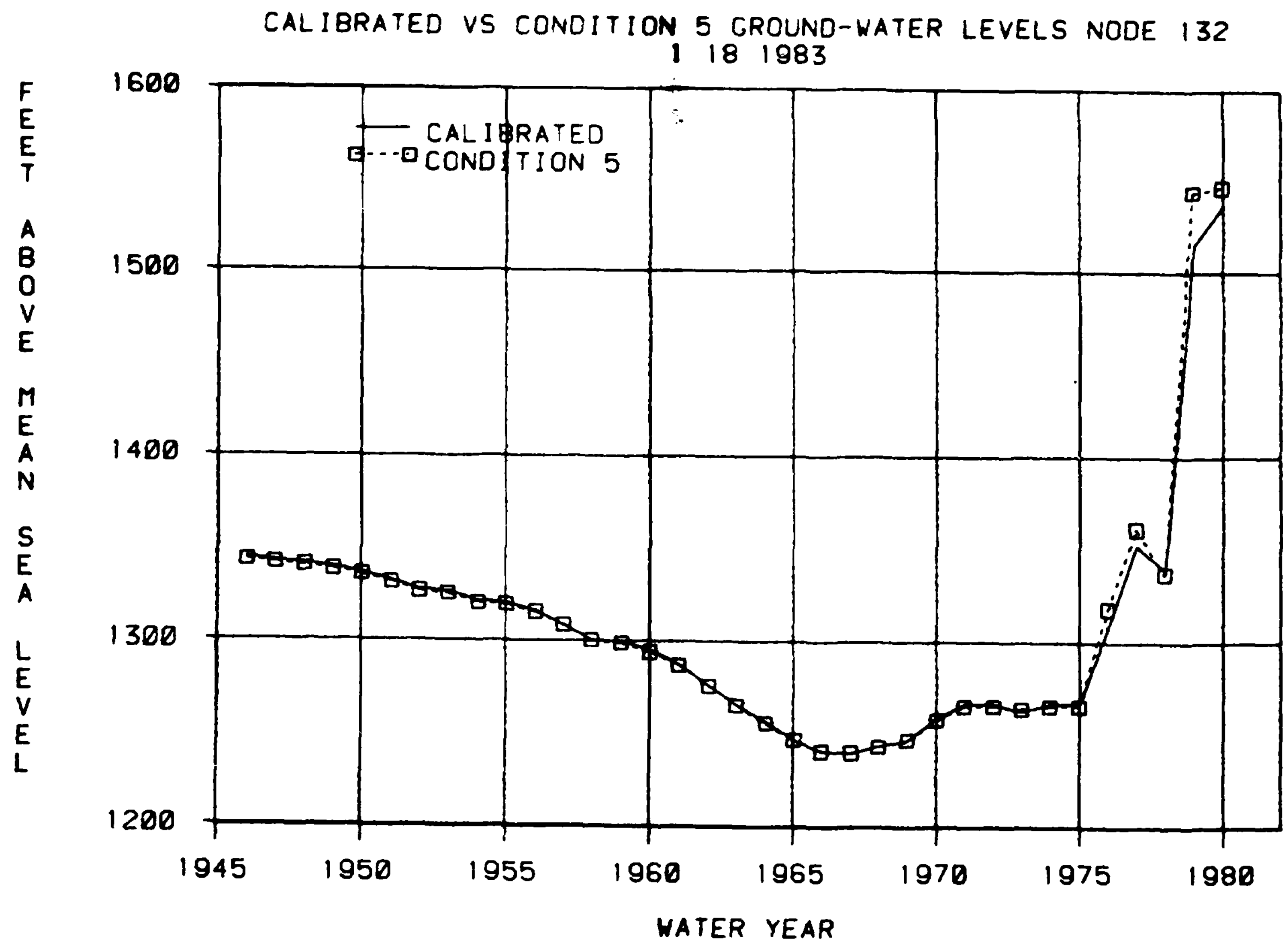

SA C5INN
CALIBRATED VS CONDITION 5 GROUND-WATER LEVELS AT NODE 123
1 12 1983
FEET ABOVE MEAN SEA LEVEL
1400
1350
1300
1250
1200
1150
1100
CALIBRATED
CONDITION 5
1945
1950
1955
1960
1965
1970
1975
1980
WATER YEAR

FIGURE 39



CALIBRATED VS CONDITION 5 GROUND-WATER LEVELS NODE 132
1 18 1983
CALIBRATED
CONDITION 5
FEET ABOVE MEAN SEA LEVEL
1600
1500
1400
1300
1200
1945
1950
1955
1960
1965
1970
1975
1980
WATER YEAR

FIGURE 40

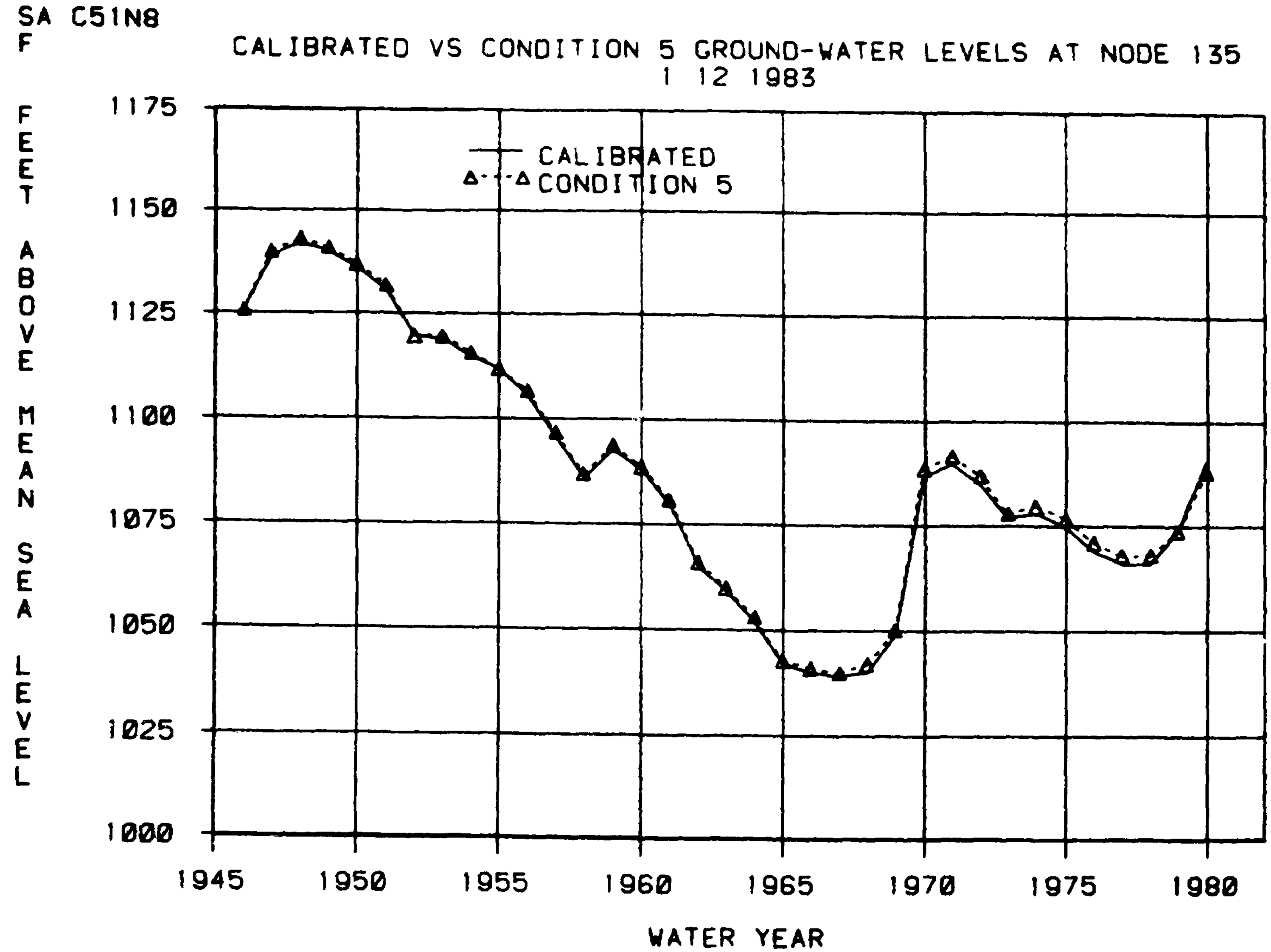
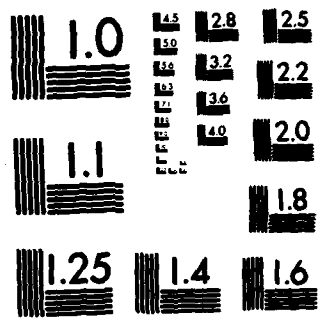

SA C51N8
CALIBRATED VS CONDITION 5 GROUND-WATER LEVELS AT NODE 135
1 12 1983
CALIBRATED
CONDITION 5
FEET ABOVE MEAN SEA LEVEL
1175
1150
1125
1100
1075
1050
1025
1000
1945
1950
1955
1960
1965
1970
1975
1980
WATER YEAR

FIGURE 41

AD-A171 478 TWO DIMENSIONAL GROUNDWATER AND SEDIMENT MODELING STUDIES SANTA ANA RIVER BASIN CALIFORNIA(U) ARMY ENGINEER DISTRICT LOS ANGELES CA JAN 83 2/2

UNCLASSIFIED F/G 8/8 NL

END
DATE
FILMED
10-86
DTIC



MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

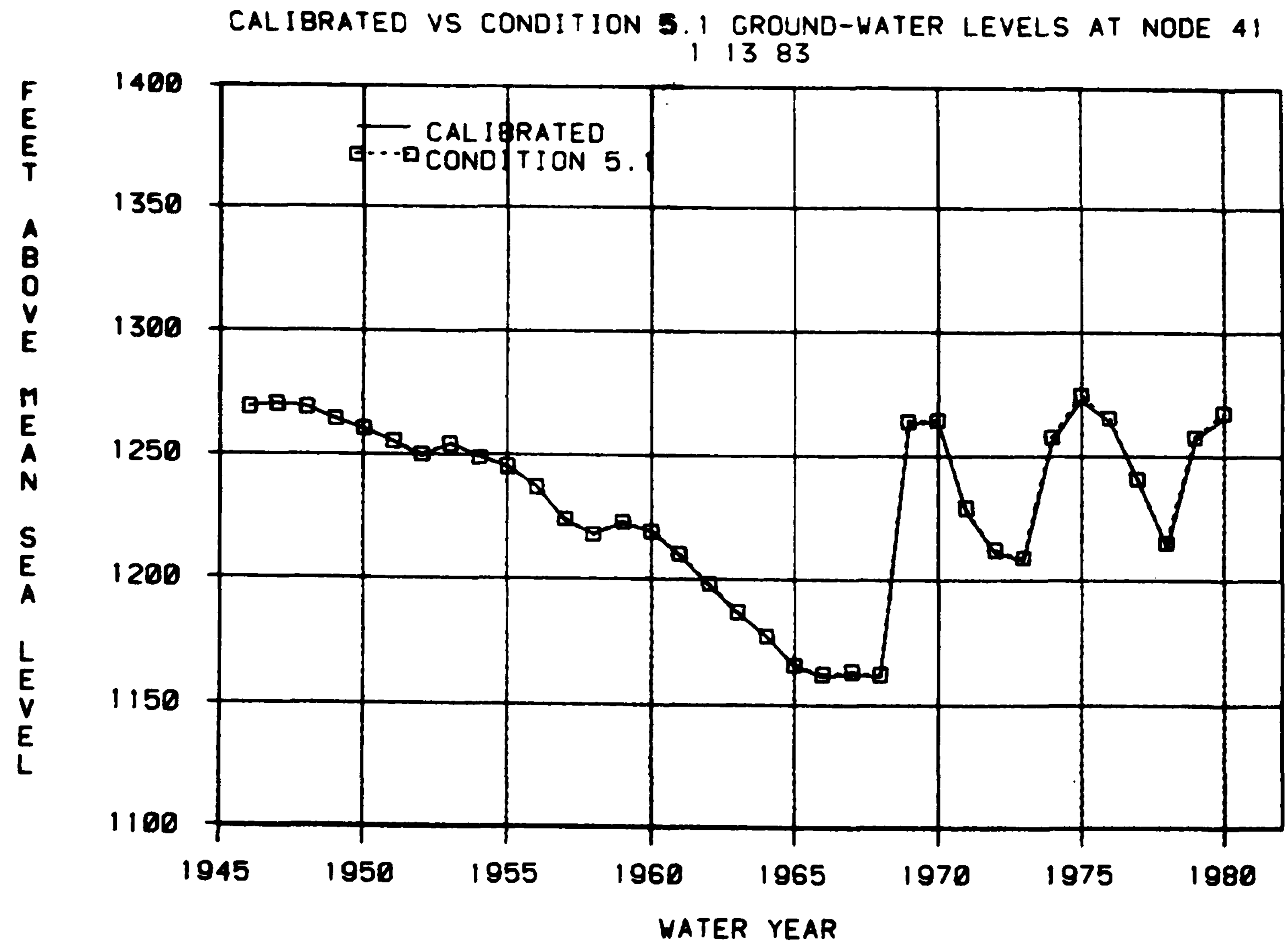

CALIBRATED VS CONDITION 5.1 GROUND-WATER LEVELS AT NODE 41
1 13 83
CALIBRATED
CONDITION 5.1
FEET ABOVE MEAN SEA LEVEL
1400
1350
1300
1250
1200
1150
1100
1945
1950
1955
1960
1965
1970
1975
1980
WATER YEAR

FIGURE 42

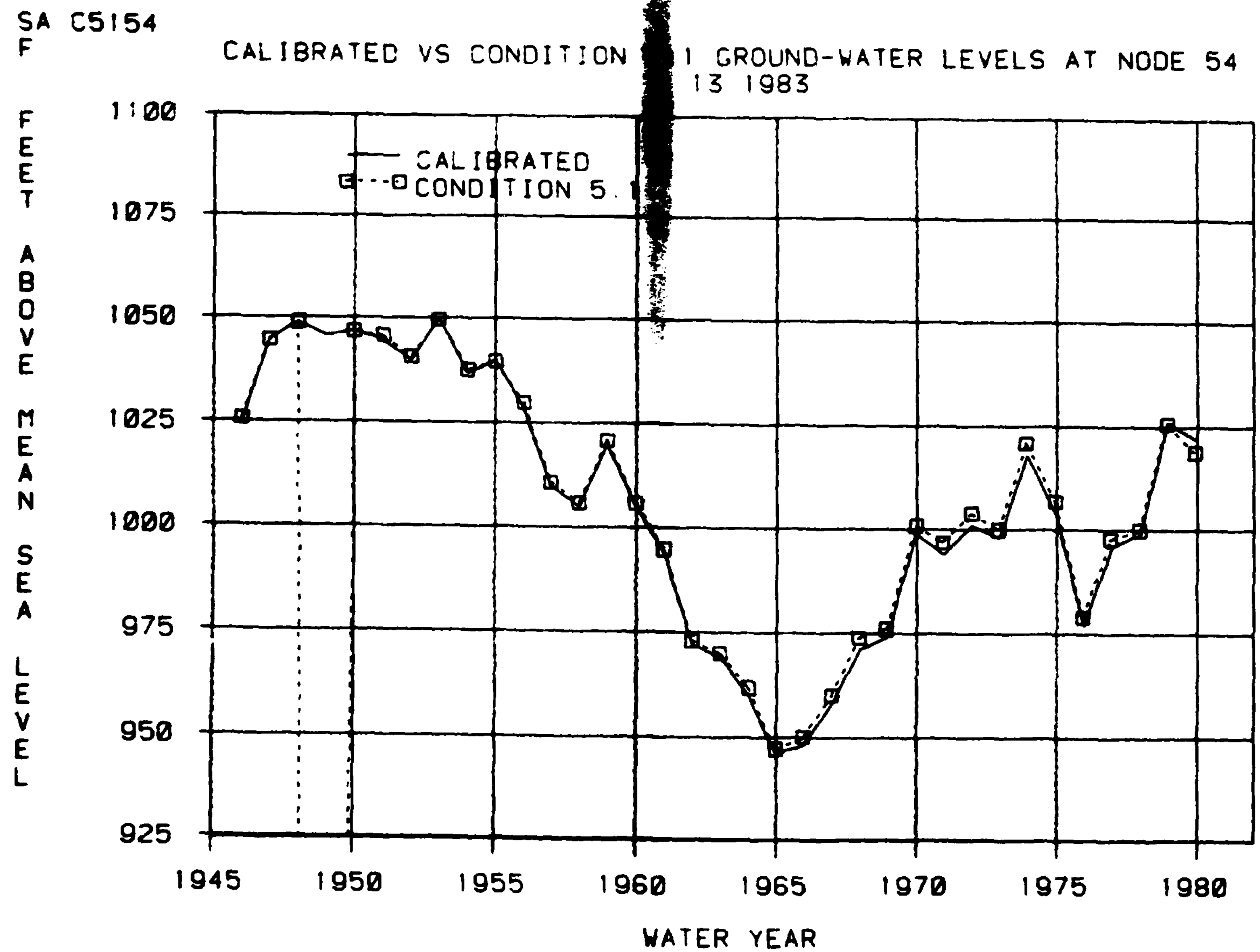
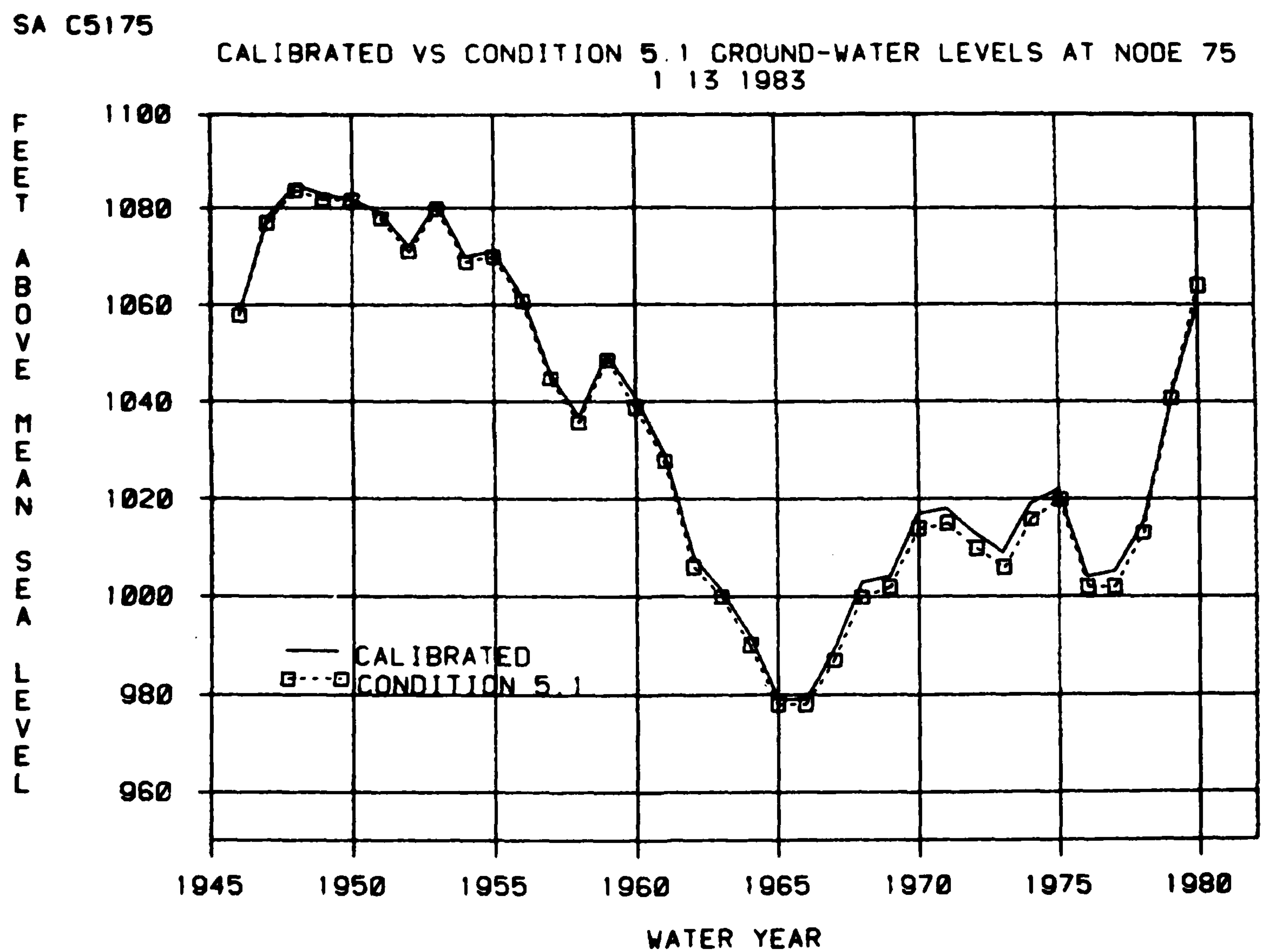

SA C5154
F
CALIBRATED VS CONDITION 5.1 GROUND-WATER LEVELS AT NODE 54
13 1983
CALIBRATED
CONDITION 5.1
FEET ABOVE MEAN SEA LEVEL
1100
1075
1050
1025
1000
975
950
925
1945
1950
1955
1960
1965
1970
1975
1980
WATER YEAR

FIGURE 43



SA C5175
CALIBRATED VS CONDITION 5.1 GROUND-WATER LEVELS AT NODE 75
1 13 1983
FEET ABOVE MEAN SEA LEVEL
1100
1080
1060
1040
1020
1000
980
960
CALIBRATED
CONDITION 5.1
1945
1950
1955
1960
1965
1970
1975
1980
WATER YEAR

FIGURE 44

SA C51121
F

CALIBRATED VS CONDITION 5.1 GROUND-WATER LEVELS AT NODE 121
1 13 1983

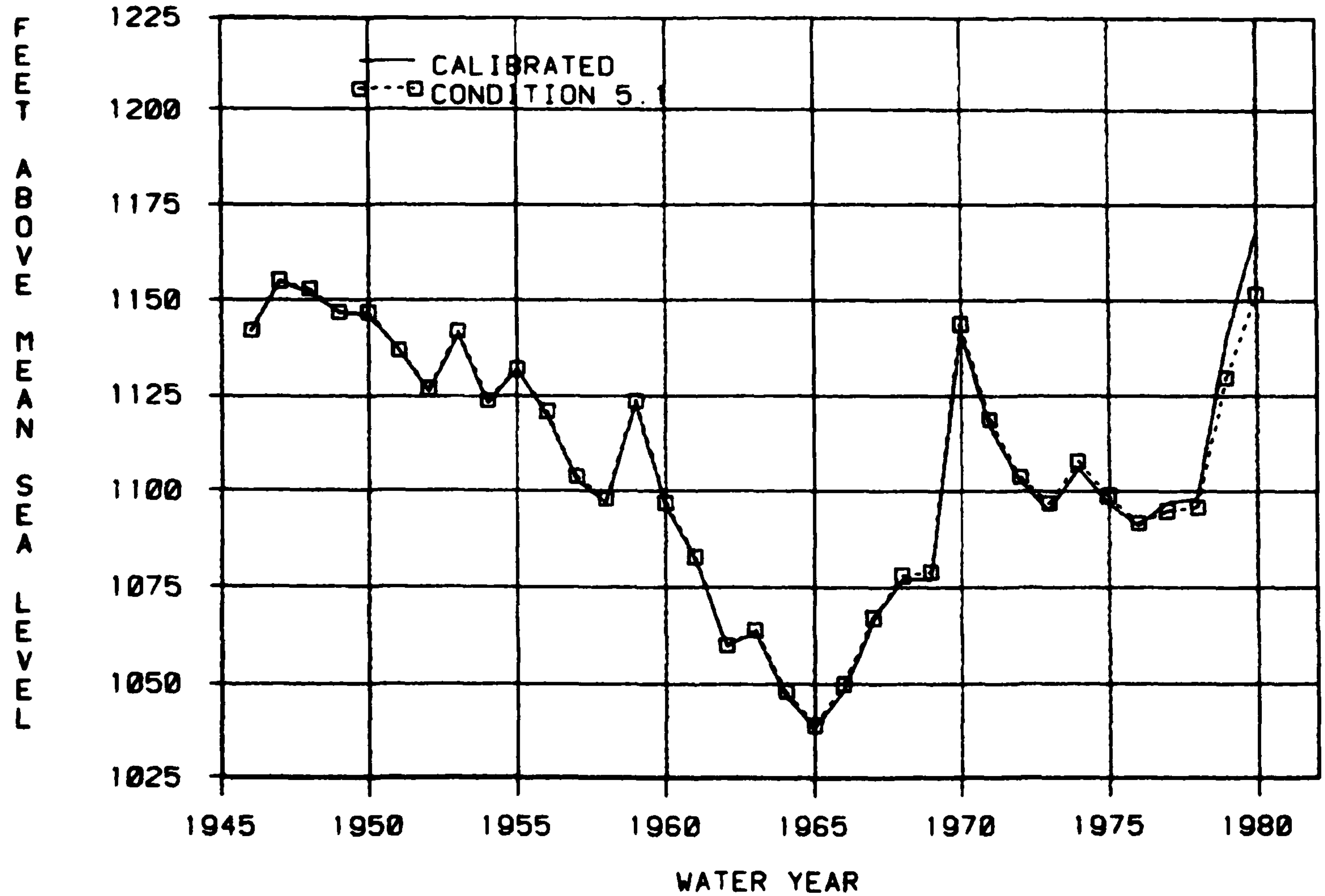


FIGURE 45

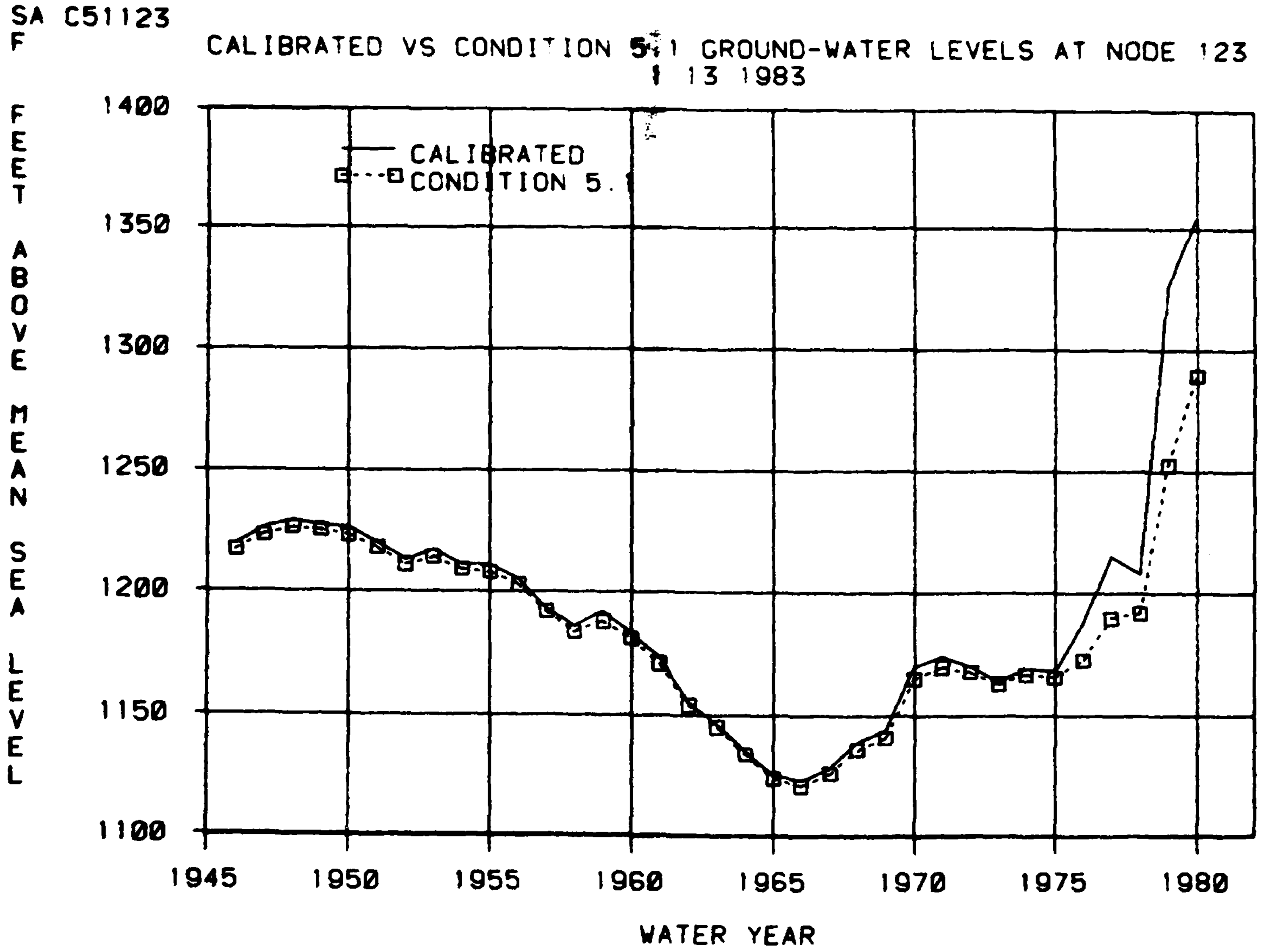

SA C51123
F
CALIBRATED VS CONDITION 5.1 GROUND-WATER LEVELS AT NODE 123
1 13 1983
CALIBRATED
CONDITION 5.1
FEET ABOVE MEAN SEA LEVEL
1400
1350
1300
1250
1200
1150
1100
1945
1950
1955
1960
1965
1970
1975
1980
WATER YEAR

FIGURE 46

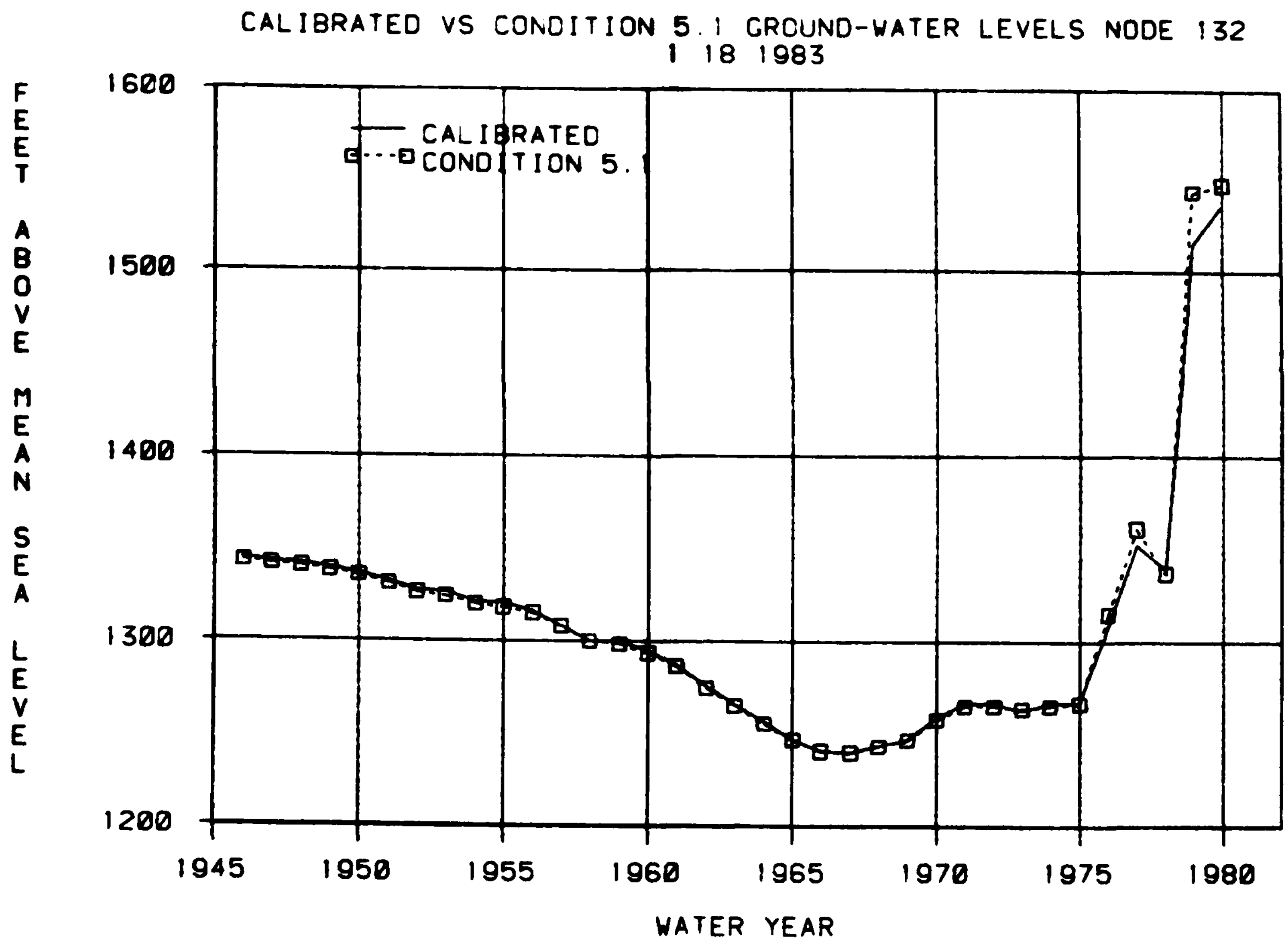

CALIBRATED VS CONDITION 5.1 GROUND-WATER LEVELS NODE 132
1 18 1983
FEET ABOVE MEAN SEA LEVEL
1600
1500
1400
1300
1200
CALIBRATED
CONDITION 5.1
1945
1950
1955
1960
1965
1970
1975
1980
WATER YEAR

FIGURE 47

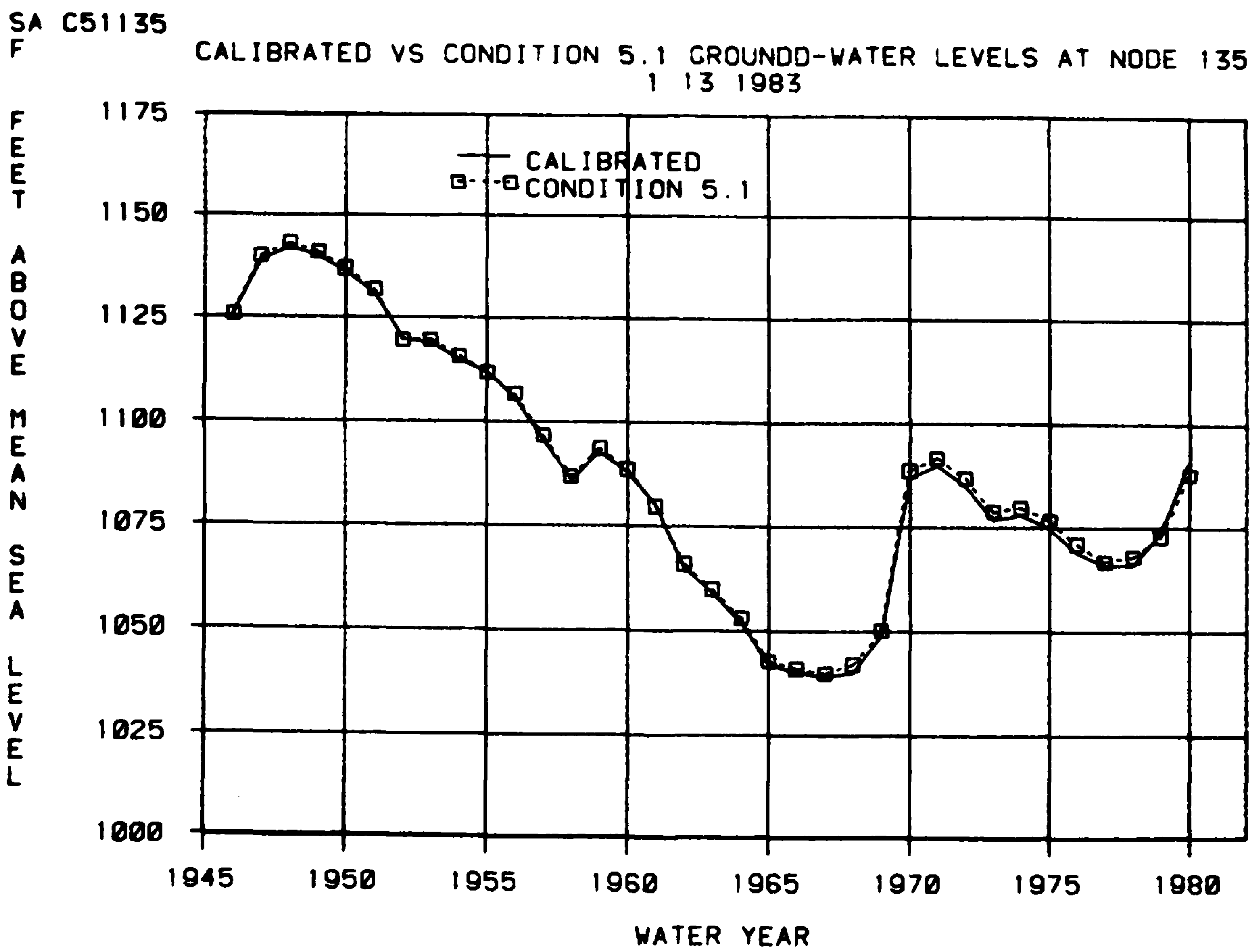

SA C51135
CALIBRATED VS CONDITION 5.1 GROUNDD-WATER LEVELS AT NODE 135
1 13 1983
F
FEET ABOVE MEAN SEA LEVEL
1175
1150
1125
1100
1075
1050
1025
1000
CALIBRATED
CONDITION 5.1
1945
1950
1955
1960
1965
1970
1975
1980
WATER YEAR

FIGURE 48

FILMED

8